EXHIBIT A

Fingerprinting of PCB congener patterns in samples from the Lower Duwamish Waterway

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Qualifications

I am a Professor of Environmental Science at Rutgers, the State University of New Jersey. I have a BA in chemistry from Wittenberg University and a PhD in Environmental Engineering from the Johns Hopkins University. I have been studying PCBs since 1998 when I began a post-doctoral fellowship at Rutgers with Dr. Steven Eisenreich, a noted PCB expert. I have extensive experience measuring PCBs in environmental samples in an academic laboratory using methods similar to EPA methods 8082 and 1668, and in interpreting PCB data from these two methods.

I have pioneered the use of factor analysis, specifically Positive Matrix Factorization (PMF), to understand the sources of PCBs to complex ecosystems that may have multiple sources of PCB contamination and display a variety of PCB weathering processes. PMF is a tool developed in the early 1990s that was originally applied to air quality data. Over the last ~30 years, it has been used more widely to examine all types of pollutants. The US EPA developed its own versions of PMF (EPA PMF 3.0 and 5.0), which it makes available for free on its website. My contribution has been to combine this tool (PMF) with new high-quality data sets in which all 209 PCB congeners have been measured in order to understand PCB sources as well as the processes that affect PCB in the environment. I used the methods described here (analysis of data sets with the PMF2 software) to investigate several systems resulting in multiple peer-reviewed publications and reports. My collected works have been cited over 1,000 times, including studies based on:

- The Delaware River (air, water, sediment, and permitted discharges) with funding from the Delaware River Basin Commission and the New Jersey Department of Environmental Protection (Du and Rodenburg, 2007a; Du et al., 2008; Du et al., 2009; Rodenburg et al., 2010a; Praipipat et al., 2013; Praipipat et al., 2017).

- The New York/New Jersey Harbor (air, water, sediment, and permitted discharges) with funding from the Hudson River Foundation (Rodenburg et al., 2011; Rodenburg et al., 2012; Rodenburg and Ralston, 2017).

- The Green-Duwamish River (atmospheric deposition, water, sediment, biota, and storm water) with funding from the State of Washington in a project overseen by the US EPA (Rodenburg and Leidos, 2017b, a).

- The Portland Harbor Superfund Site (water and sediment) (Rodenburg et al., 2015c).

- The city of Chicago (atmospheric deposition) (Rodenburg and Meng, 2013).

- The Hanford Site in Hanford, Washington (biota) (Rodenburg et al., 2015a).

- The Spokane River near Spokane, Washington (surface water, stormwater, wastewater (both influent and treated effluent), fish, groundwater, and other matrices (Rodenburg et al., 2020).

In these studies, I have identified PCB sources that are not related to Monsanto's Aroclors or other intentionally–produced commercial PCB formulations, including PCBs generated inadvertently during various chemical processes such as the production of pigments, as well as the dechlorination of parent PCB congeners (most likely arising originally from commercial formulations) by bacteria. As a result, I am recognized as an international expert in non-commercial PCB sources, having published several peer-reviewed papers on this subject (Rodenburg et al., 2010b; Guo et al., 2014; Rodenburg et al., 2015b). I served as an expert witness on this subject for the State of Washington (Department of Ecology) at the August 2012 meeting of the Environmental Council of States. My research on this subject led to my appearances on Good Morning America in 2014 and news coverage in outlets such as Scientific American, Environmental Health Perspectives, Environmental Health News, and Yahoo! News.

My expertise on the subject of PCB sources and fate has been recognized by the Hudson River Foundation, where I serve as a member of their Science and Technical Advisory Committee for the New York/New Jersey Harbor & Estuary Program. I am currently an advisor to the Spokane River Regional Toxics Task Force (SRRTTF). I have also served on the Expert Panel advising the Delaware River Basin Commission on establishment of a Total Maximum Daily Load (TMDL) for PCBs in the Delaware River.

For additional qualification information, see my CV attached as Exhibit A.

Compensation

My general billing rate is $250 per hour. My rate for testimony is $350 per hour.

Testimony in Past 4 Years

City of Hartford, et al. v. Monsanto Company, et al. – February 7, 2018

City of San Diego, et al. v. Monsanto Company, et al. – June 14, 2019

City of Spokane v. Monsanto Company, et al. – December 18, 2019

Summary of opinions

In my expert opinion, Aroclors produced by Monsanto and not byproduct PCBs, are the dominant (in most cases, greater than 95% of the total) sources of PCBs to all seven of the environmental compartments of the Lower Duwamish Waterway that I examined.

The foundation for my opinions is the analysis I conducted for the Department of Ecology of the State of Washington under subcontract to Leidos in 2016-2017. The Green-Duwamish River Watershed PCB Congener Study was part of a larger program to investigate the Green-Duwamish River system. As described in (Rodenburg and Leidos, 2017a), "The Washington State Department of Ecology (Ecology) and U.S. Environmental Protection Agency (EPA) [were] jointly developing a Pollutant Loading Assessment (PLA) for the Green-Duwamish River watershed to understand the relationship of water, sediment, and fish tissue quality to the overall health of the watershed, and to determine ways to reduce ongoing sources of pollution. The PLA includes watershed, receiving water, and food web modeling of selected pollutants, including polychlorinated biphenyls (PCBs)." The purposes of the PCB congener portion of the study were to provide "recommendations on which PCB congener(s), suite of PCB congeners, homologs, or Monsanto's Aroclor(s) would be the most appropriate candidates for modeling in the PLA," and to identify "potential sources of PCBs in the Green-Duwamish watershed to inform source control priorities for the Lower Duwamish Waterway (LDW) Superfund site." This study was not, therefore, originally related to any litigation.

The results of my portion of the Green-Duwamish River Watershed PCB Congener Study were disseminated via two main reports (Rodenburg and Leidos, 2017a, 2018). In this report, I have interpreted that analysis to specifically address the issue of inadvertent vs. Monsanto's Aroclor PCB sources and to focus on only the Lower Duwamish Waterway (LDW). I did not re-run any PMF analysis, except for the water column (see "Summary of results from new data sets" below). I re-ran the water column analysis because a significant number of new samples became available.

In the first of these reports (Rodenburg and Leidos, 2017a), I analyzed the congener-specific data on PCBs that was available for the Green-Duwamish river at that time. Later, two new data sets on PCBs in otter scat and groundwater became available, so these were analyzed in an addendum to the main report (Rodenburg and Leidos, 2018). Collectively, these are referred to in this opinion as the "GD reports". These reports describe the second phase of a larger project, where phase 1 consisted of compiling the available data (Leidos, 2015) and an earlier part of phase 2 consisted of evaluating the quality of the data to determine whether it was sufficient to perform fingerprinting using the PMF approach (Rodenburg and Leidos, 2017b). Thus, all data used in the GD reports went through careful quality assurance procedures, not only during the initial collection of the data, but also during the storage, management, and transmission of the data. In addition, we conducted a careful analysis of the uncertainty in the results and concluded that the results were reliable for most media, including sediment, tissue, atmospheric deposition, and stormwater/storm solids. The one medium for which the results

were not reliable was water, due to a limited amount of data. This is no longer a concern because additional water samples were analyzed for this report, as noted above.

Through my analysis, as discussed throughout this report, I have developed the following opinions, discussed here by environmental compartment. In all compartments, Monsanto's Aroclors are the dominant source of PCBs in the Lower Duwamish Waterway (LDW).

- In LDW sediment, PCBs arise almost exclusively (>99%) from Monsanto's Aroclors.
- In LDW surface water, PCBs arise almost exclusively (>99%) from Monsanto's Aroclors.
- In the tissues of organisms from the LDW, PCBs arise almost exclusively (>99%) from Monsanto's Aroclors.
- In otter scat gathered on the banks of the LDW, PCBs arise overwhelmingly (99%) from Monsanto's Aroclors.
- In the storm drain solids and storm water samples from stormwater drainage pipes connected to the LDW, PCBs arise overwhelmingly (>95%) from Monsanto's Aroclors.
- In samples of air deposition from near the LDW, at least 87% of the PCBs arise from Monsanto's Aroclors.
- In groundwater that drains into the LDW, Monsanto's Aroclors are virtually the only source (>99%) of PCBs.

Introduction

Samples of a wide variety of environmental compartments in the Seattle, WA area were analyzed for this report. I conducted the bulk of this analysis for the Department of Ecology of the State of Washington under subcontract to Leidos in 2016-2017. The findings were disseminated via two main reports (Rodenburg and Leidos, 2017a, 2018). In this report, I have specifically addressed the issue of inadvertent vs. Monsanto's Aroclor PCB sources and focused on only the Lower Duwamish Waterway (LDW). This report should be interpreted as an addendum to those previous reports. For this reason, I have not reproduced any figures that could be found in the previous reports.

In addition to the data already analyzed in the previous reports (Rodenburg and Leidos, 2017a, 2018), I examined data obtained from the Lower Duwamish Waterway Group (LDWG) online project library at https://ldwg.org/project-library/.

The purpose of this work was to examine the congener patterns in these samples in an attempt to determine whether the PCBs in these samples arose from Aroclors produced by Monsanto, and if so to quantify the fraction of the total PCBs in each sample that is attributable to Monsanto's Aroclors versus the fraction attributable to non-Aroclor ('inadvertent' or 'byproduct') sources.

As explained in more detail below, I used Positive Matrix Factorization (PMF) to analyze data from the following compartments:

- Air deposition; see also Rodenburg et al. (2019)
- Sediment
- Surface water
- Tissue
- Storm drain solids and stormwater
- Otter scat
- Groundwater

These data have been collected under various Quality Assurance Project Plans (QAPPs). Data was obtained via Leidos, who primarily obtained data from the Washington State Environmental Information Management (EIM) System. Details of their data validation are presented in (Leidos, 2015).

Measurement of PCBs

The congener-specific PCB data evaluated here were collected using U.S. Environmental Protection Agency (EPA) Method 1668, which was first published in 1999 and has undergone several revisions since then (EPA, 1999). The first version was Method 1668A, and subsequent minor revisions are denoted as 1668B, 1668C, and 1668D. There is relatively little difference between the various revisions, and data collected under different revisions are highly comparable and can generally be pooled and used together. Method 1668 uses a high-resolution mass spectrometer (MS) coupled with high-resolution gas chromatography (GC) to measure PCBs in any matrix. Chromatography is the science of separating a mixture into its individual components by injecting the mixture into a mobile phase, which then passes through a stationary phase. Some compounds in the mixture spend more time sorbed onto the stationary phase. Because these compounds spend more time not moving, they will emerge (elute) from the chromatographic system later. The amount of time a compound takes to travel through the chromatographic system is its retention time. In GC, the mobile phase is a gas (usually helium), and the stationary phase can be any one of a number of organic compounds chemically bonded to a stationary support. There are hundreds of GC columns commercially available. The primary mechanism causing some PCB congeners to be retained longer on any of these columns is their condensation on the stationary phase; therefore, the primary chemical property that determines the retention time is the compound's vapor pressure. The type of stationary phase has a lesser, but still important, impact on the compound's retention time.

There are 209 PCB congeners. A homologue group is a set of congeners that have the same number of chlorines. The MS used in Method 1668 can discern between different masses of the PCB molecule; therefore, congeners that have the same retention time but different masses

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(i.e., different homologues) can be quantified separately. The key difficulty in measuring PCBs is that, within a homologue group, there are often several congeners that are so similar in their vapor pressure that they have essentially the same retention time; therefore, they cannot be quantified separately and can only be reported as the sum of multiple congeners. One of the primary goals when developing Method 1668 was to find a column that would resolve the 12 dioxin-like PCB congeners into 12 separate peaks, each with its own unique retention time, such that none of the 12 coelute with any other PCB congener. This would allow the results to be used to calculate a toxic equivalency quotient (TEQ) by multiplying the concentration of each dioxin-like congener by its corresponding toxic equivalency factor (TEF).

Separating the 12 dioxin-like congeners from all the others is difficult. Even after much effort, Method 1668 could only separate 10 of the 12 completely, with the 2 remaining dioxin-like congeners (PCB-156 and PCB-157) coeluting with each other using an SPB-octyl column. Fortunately, PCB-156 and PCB-157 have the same TEF; therefore, the calculation of the TEQ was not affected. However, the column that had been most commonly used for PCB analysis since the 1980s could separate PCB-156 and PCB-157 into 2 separate peaks, but it could not resolve all of the other 10 dioxin-like congeners. This column is referred to as DB-1 in Method 1668, but it is also referred to as DB-5, as well as a number of other names. The authors of Method 1668 allowed this column as an alternate. As written, Method 1668 requires the use of "[a]ny GC column or column system (2 or more columns) that provides unique resolution and identification of the Toxics for determination of a TEQPCB using TEFs...Isomers may be unresolved so long as they have the same TEF and response factor and so long as these unresolved isomers are uniquely resolved from all other congeners. For example, the SPB-octyl column…achieves unique GC resolution of all Toxics except congeners with IUPAC numbers 156 and 157. This isomeric pair is uniquely resolved from all other congeners and these congeners have the same TEF and response factor…The DB-1 column is optional and is capable of uniquely resolving the congener pair with IUPAC 156 and 157" (EPA, 1999). In addition, SGE Analytical Science produces a column called the SGE-HT8, which is capable of resolving more congeners than the DB-5 and is more rugged than the SPB-octyl.

As noted, there is no column that can separate all 209 congeners into 209 separate peaks. Some congeners will always coelute. The problem is that the coelution patterns are very different on the SPB-octyl, SGE-HT8, and DB-5 equivalent columns. Table 1 summarizes the most common coelution patterns, but differences can be observed depending on the lot and age of the GC column. These differences are usually minor for the SPB-octyl and DB-5 columns, but the coelution patterns can vary substantially on the SGE-HT8 column.

As Table 2 demonstrates, if the goal is to mix data collected on the different types of columns into a single data set for analysis, the concentrations reported for a variety of congeners must sometimes be summed. One example is PCB-85. On the DB-5 column, six separate reported concentrations must be summed to equal the sum of three reported concentrations from the SPB-octyl column, which yields a single concentration representing the sum of PCB congeners 85, 86, 87, 97, 108, 112, 116, 117, 119, and 125. Information is lost. As a result, while the DB-5

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column reports the 209 PCBs in about 168 chromatographic peaks, and the SPB-octyl column reports the 209 congeners in about 159 peaks, a data set in which SPB-octyl and DB-5 data have been combined will contain only about 128 peaks. A data set in which all three types of columns have been used will contain only about 122 peaks after they are composited. For these reasons, I avoided compositing data whenever possible.

Table 2. PCB Congener Coelution Patterns on the DB-5 (or equivalent), SGE-HT8, and SPB-octyl GC Columns. Reproduced from (Rodenburg and Leidos, 2017b).

DB-5	SGE-HT8	SPB-octyl
PCB-4+10	PCB-4	PCB-4
	PCB-10	PCB-10
PCB-5+8	PCB-5+8	PCB-5
		PCB-8
PCB-7+9	PCB-7	PCB-7
	PCB-9	PCB-9
PCB-12+13	PCB-12+13	PCB-12+13
PCB-16+32	PCB-16	PCB-16
	PCB-32	PCB-32
PCB-18	PCB-18	PCB-18+30
PCB-30	PCB-30	
PCB-20+21+33	PCB-20+33	PCB-20+28
PCB-28	PCB-21	PCB-21+33
	PCB-28	
PCB-24+27	PCB-24	PCB-24
	PCB-27	PCB-27
PCB-26	PCB-26	PCB-26+29
PCB-29	PCB-29	
PCB-40	PCB-40+57	PCB-40+41+71
PCB-41+64+71+72	PCB-41	PCB-57
PCB-57	PCB-64+72	PCB-64
	PCB-71	PCB-72
PCB-42+59	PCB-42	PCB-42
PCB-43+49	PCB-43+49	PCB-43
PCB-44	PCB-44	PCB-44+47+65
PCB-47	PCB-47+48	PCB-48
PCB-48+75	PCB-52+69	PCB-49+69
PCB-52+69	PCB-49	PCB-52
PCB-62	PCB-62	PCB-59+62+75
PCB-65	PCB-65+75	
PCB-45	PCB-45	PCB-45+51
PCB-51	PCB-51	
PCB-50	PCB-50	PCB-50+53

DB-5	SGE-HT8	SPB-octyl
PCB-53	PCB-53	
PCB-56+60	PCB-56	PCB-56
	PCB-60	PCB-60
PCB-61+70	PCB-61	PCB-61+70+74+76
PCB-66+76	PCB-66	PCB-66
PCB-74	PCB-70	
	PCB-74	
	PCB-76	
PCB-83	PCB-83+109	PCB-83+99
PCB-85+116	PCB-85	PCB-85+116+117
PCB-86	PCB-86+97+117	PCB-86+87+97+108+119+125
PCB-87+117+125	PCB-87+115	
PCB-97		
PCB-99	PCB-99	
PCB-107+109	PCB-107+108	PCB-107+124
PCB-108+112		PCB-109
PCB-110	PCB-110	PCB-110+115
PCB-111+115	PCB-111	PCB-111
PCB-119	PCB-112+119	PCB-112
	PCB-116+125	
PCB-124	PCB-124	
PCB-84+92	PCB-84	PCB-84
	PCB-92	PCB-92
PCB-88+91	PCB-88	PCB-88+91
	PCB-91	
PCB-93	PCB-93+98+102	PCB-93+95+98+100+102
PCB-95+98+102	PCB-95	
PCB-100	PCB-100	
PCB-90+101	PCB-90	PCB-90+101+113
PCB-113	PCB-101	
	PCB-113	
PCB-105	PCB-105+127	PCB-105
PCB-127		PCB-127
PCB-106+118	PCB-106	PCB-106
	PCB-118	PCB-118
PCB-128+162	PCB-128	PCB-128+166
PCB-166	PCB-162	PCB-162
	PCB-166	
PCB-129	PCB-129	PCB-129+138+160+163
PCB-138+163+164	PCB-138	PCB-158

DB-5	SGE-HT8	SPB-octyl
PCB-158+160	PCB-158	PCB-164
	PCB-160	
	PCB-163+164	
PCB-132+161	PCB-132+161	PCB-132
		PCB-161
PCB-133+142	PCB-133	PCB-133
	PCB-142	PCB-142
PCB-135	PCB-135	PCB-135+151+154
PCB-151	PCB-151	
PCB-154	PCB-154	
PCB-136	PCB-136+148	PCB-136
PCB-148		PCB-148
PCB-134+143	PCB-134	PCB-134+143
PCB-139+149	PCB-139+149	PCB -139+140
PCB-140	PCB-140	PCB-146
PCB-146+165	PCB-143	PCB-147+149
PCB-147	PCB-146	PCB-165
	PCB-147	
	PCB-165	
PCB-153	PCB-153	PCB-153+168
PCB-168	PCB-168	
PCB-156	PCB-156	PCB-156+157
PCB-157	PCB-157	
PCB-171	PCB-171	PCB-171+173
PCB-173	PCB-173	
PCB-180	PCB-180	PCB-180+193
PCB-193	PCB-193	
PCB-182+187	PCB-182+187	PCB-182
		PCB-187
PCB-183	PCB-183	PCB-183+185
PCB-185	PCB-185	
PCB-196+203	PCB-196	PCB-196
	PCB-203	PCB-203
PCB-197	PCB-197	PCB-197+200
PCB-200	PCB-200	
PCB-198	PCB-198	PCB-198+199
PCB-199	PCB-199	

Congeners that do not coelute on any column are not shown.

GC = Gas chromatography.

PCB = Polychlorinated biphenyl.

Background on PMF

The primary technique used here is factor analysis using Positive Matrix Factorization (PMF) (Paatero and Tapper, 1994). This approach has been used extensively in the environmental literature to investigate PCB sources by the author of this report (Du and Rodenburg, 2007b; Du et al., 2008; Rodenburg et al., 2010a; Rodenburg et al., 2011; Rodenburg et al., 2012; Praipipat et al., 2013; Rodenburg and Meng, 2013; Rodenburg et al., 2015a; Rodenburg et al., 2015c; Praipipat et al., 2017; Rodenburg and Ralston, 2017) and many other researchers (Magar et al., 2005; Bzdusek et al., 2006a; Bzdusek et al., 2006b; Soonthornnonda et al., 2011; Uchimiya et al., 2011; Saba and Su, 2013; Karakas et al., 2017). As these references suggest, the combination of PMF analysis with high-quality PCB data generated by EPA method 1668 has proven a powerful approach to identifying PCB sources in a variety of systems.

PMF defines the sample matrix as product of two unknown factor matrices with a residue matrix:

$$X = GF + E \tag{1}$$

The sample matrix (X) is composed of n observed samples and m chemical species. F is a matrix of chemical profiles of p factors or sources. The G matrix describes the contribution of each factor to any given sample, while E is the matrix of residuals. The PMF solution, i.e. G and F matrices, are obtained by minimizing the objective function Q through the iterative algorithm:

$$Q = \sum_{i=1}^{n} \sum_{j=1}^{m} (e_{ij} / s_{ij})^2 \tag{2}$$

Q is the sum of the squares of the difference (i.e. e_{ij}) between the observations (X) and the model (GF), weighted by the measurement uncertainties (s_{ij}). For the Green-Duwamish project and in this report, I have used the PMF2 software of Paatero and Tapper (1994), which I have used throughout all of my published work.

The PMF approach looks for patterns that exist in the data. It does not 'look' for Monsanto's Aroclors. The PMF approach can quantify the fraction of a given congener that comes from different sources, for example from Monsanto's Aroclors versus non-Aroclor sources, and it does not make the assumption that no weathering of the PCB fingerprints has taken place. Instead it produces fingerprints of congeners that co-vary and have been found to be present in most of the samples. The user can then compare these fingerprints to the congener patterns of Monsanto's Aroclors to determine whether they are similar.

All data analysis approaches require that the input data be processed in some way. The data processing methods used in the GD reports and in this report are the same as those used in my peer-reviewed publications. The analysis performed the GD report was designed to be publishable in peer-reviewed journals, and the air analysis was published (Rodenburg et al.,

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2019). As discussed in the section on uncertainty in the GD reports, in order for the PMF program to reliably identify sources, it needs to have an adequate quantity of data and the data needs to be of sufficient quality. One of the main issues of data quality is the number of non-detects; there should be a relatively low proportion of non-detects to yield reliable results. These two conditions were met for most of the data sets including sediment, tissue, atmospheric deposition, and stormwater/storm solids. The one compartment that did not yield reliable results was water. This is no longer a concern because additional water samples were analyzed for this report, as described below.

Interpreting PMF results

The focus of much of my published work has been to determine the sources of PCBs in the environment. Prior to the publication of EPA method 1668 in 1999, PCBs were usually measured as Monsanto's Aroclors, meaning that the methods did not even try to measure non-Aroclor PCBs, based on the assumption that all PCBs encountered in the environment arise from commercial formulations. Method 1668 used a different approach and measured all 209 PCB congeners. As soon as scientists and regulators started using this new method, they began to find PCBs that did not appear to be associated with Monsanto's Aroclors. I became aware of non-Aroclor PCB sources via the work of Litten et al. (2002) in the New York/New Jersey Harbor who identified the congener PCB 11 from pigments in the treated effluent from a wastewater treatment plant in New Jersey that received process waste from a pigment manufacturer. I learned that non-Aroclor PCBs could come from the production of titanium dioxide (white pigment) via my work with the Delaware River Basin Commission (Totten et al., 2007). Since then, I (and many other researchers) have worked to determine the significance of non-Aroclor PCBs. In more than ten years of searching, I have only identified one additional source of inadvertent PCBs that is relevant in environmental samples: silicone products, such as silicone rubber tubing and caulk. I am currently working to determine whether these silicone-derived PCBs are truly an environmental problem or if they are artifacts that enter samples when silicone products are used by the people who collect the samples and by the labs that analyze them. My recent work in the Spokane River suggests that silicone is usually an artifact and not a real contributor to PCBs in the environment (Rodenburg et al., 2020).

This history explains why I have always used a 'weight of evidence' approach to identifying PCB sources. Once the PMF program generates factors or fingerprints, these are interpreted by examining their congener patterns as well as their spatial/temporal variations and any other available information. Throughout my published works, I have considered the question of whether PCBs originated from the Monsanto's Aroclors or from non-Aroclor sources. When PCBs are found in a primary source such as in a transformer or in building caulk, it can be safely assumed that they have undergone minimal 'weathering', meaning that the congener patterns in the sample ought to closely resemble those in the original Monsanto's Aroclors. However, the samples considered here are, like most of the data I have analyzed in my published works, from environments such as sediment and fish tissue. In those media, the PCBs may have

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traveled a long way and have resided in the fish or sediment for a long time, which allows many weathering processes to alter their fingerprints somewhat, a process akin to the smudging of a human fingerprint over time. These weathering processes can alter the congener patterns so that they are no longer identical to those produced by Monsanto (see for example (Chiarenzelli et al., 1997)). Weathering processes usually change the relative abundance of different congeners, but only in in the case of microbial dechlorination, discussed below, do they transform one congener into another. Therefore, the correlation coefficient (R^2) match between the PMF-generated fingerprint and the original Aroclor might be lower than the perfect 1.00, not because different congeners are present but because the relative amounts of each congener have changed.

In my published research (Chitsaz et al., 2020), I have used the interpretation that when the R^2 between the fingerprint produced by the PMF program and a single Aroclor is greater than approximately 0.8, the factor was considered to represent an unweathered single Aroclor. When the R^2 value was between approximately 0.4 and 0.8, the factor was interpreted as representing a weathered Aroclor. This same set of criteria was used in the GD reports. The R^2 value is used in this case as a measure of similarity. One way to interpret this is to say the when the R^2 is 0.80, the fingerprint is 80% similar to Monsanto's Aroclor. The regressions that produce these R^2 values will all be highly significant, meaning that their p values will be much less than 0.05. For example, the R^2 value for the comparison of one of the sediment fingerprints below compared to Monsanto's Aroclor 1242 is 0.42, but the p value is 0.0000000006, highly significant. The likelihood that a non-Aroclor source would produce a fingerprint that so closely resembles one of Monsanto's Aroclors is remote.

Notably, however, the R^2 is only one line of evidence used to determine whether a fingerprint represents one of Monsanto's Aroclors. In addition to calculating an R^2 value, in my published works, the GD report, and this report, I have always visually examined fingerprints to determine whether they contain congeners that are characteristic of Monsanto's Aroclors or, alternatively, non-Aroclor sources. I also use the information available about the uses of Monsanto's Aroclors in the watershed and the presence of factories that use other chemical processes that might generate non-Aroclor PCBs. In some cases, I have found fingerprints that are similar to Monsanto's Aroclors, but based on the available evidence, I have concluded that are from non-Aroclor sources (Du et al., 2008; Praipipat et al., 2013).

Another line of evidence that I consider is whether the differences between Monsanto's Aroclors and the factor cannot be explained by any known weathering phenomenon. Weathering processes include partitioning between air, water, or sediment as well as metabolism by biota or bacteria. Often PMF generates factors from biota that are not similar to Monsanto's Aroclors, but the differences conform with current knowledge about the metabolism of PCB congeners via the cytochrome P-450 pathway (Boon et al., 1997). Similarly, in anaerobic environments, bacteria are able to remove one or more of the chlorines from the PCB molecule, turning one PCB congener into another. This process is well understood, and

produces a characteristic congener pattern (Bedard, 2003; Rodenburg et al., 2010a; Rodenburg et al., 2012; Rodenburg et al., 2015c; Capozzi et al., 2019; Chitsaz et al., 2020).

Another line of evidence that I consider is that non-Aroclor source fingerprints will probably contain congeners that are known to be associated with non-Aroclor sources. For this reason, in order to identify non-Aroclor PCB sources, it is important to include PCB congeners in the PMF input data sets that are known to be associated with non-Aroclor sources. The types of congeners often found in non-Aroclor or inadvertent sources are discussed in the section below titled "Non-Aroclor PCB congeners." In the same way that I calculate an R^2 value to evaluate the similarity of a PMF-generated factor to Monsanto's Aroclors, I also calculated R^2 values for the comparison of PMF-generated factors to non-Aroclor sources. However, this comparison is less definitive than the comparison to Monsanto's Aroclors for several reasons. First, the Aroclors were manufactured by only one company, Monsanto, at only two plants in the US. The composition of Monsanto's Aroclors were remarkably constant over the many decades that they were manufactured. The exception that proves the rule is Monsanto's Aroclor 1254: Monsanto changed the process used to manufacture this Aroclor in 1974 (Agency for Toxic Substances and Disease Registry (ATSDR), 2000), but even this change resulted in only slight differences in the congener composition of the final product. In my published works, I have never tried to differentiate between 'late' and 'early' Aroclor 1254. In contrast, the types of products that may contain inadvertent PCBs, such as silicone and pigments, are produced by a wide variety of companies at locations around the world. The Japanese Ministry of Economy Trade and Industry (METI) (2012); (The Japanese Ministry of Economy Trade and Industry (METI), 2013) found large variations in the concentrations of PCBs in several batches of pigments. This suggests that the congener patterns might vary as well. Second, there are relatively few published measurements of inadvertent PCBs in raw materials such as pigment and silicone. There are more publications that present measurements of PCBs in finished consumer products, but these are not as helpful since those products could potentially contain Monsanto's Aroclors as well. Third, the few published measurements of PCBs in raw materials did not always measure PCB congeners, and even when they did, they often used older measurement methods and/or had different coelution patterns, which makes the comparison with the method 1668 data considered in this report less exact. Despite these difficulties, I did compare the PMF-derived fingerprints with those of iPCBs taken from literature sources representing silicone and pigments (Perdih and Jan, 1994; Litten et al., 2002; Hu and Hornbuckle, 2009; Anezaki and Nakano, 2014; Anezaki et al., 2015; Anezaki and Nakano, 2015). I used the same criteria as for the Monsanto's Aroclors: any correlation with an R^2 value greater than 0.4 was examined to determine whether the correlation was based on multiple congeners and not just one or two. I also considered whether the PMF-derived fingerprint was more similar to one of Monsanto's Aroclors than to an iPCB fingerprint by comparing the R^2 values as well as examining the fingerprints visually.

Taken together, these lines of evidence allow me to identify non-Aroclor PCB sources. Note that in the PMF results presented below, there are often fingerprints that might include both Monsanto's Aroclor and non-Aroclor PCBs because they are moving together in the

environment. In those cases, I have allocated the entire fingerprint to the non-Aroclor category. The odds that a non-Aroclor source of PCBs would produce a fingerprint that resembles one of (or a mix of) Monsanto's Aroclors with an R^2 greater than 0.4 but does not contain any congeners that are characteristic of non-Aroclor sources are small enough to be negligible, in my judgement.

By relying on these multiple lines of evidence, I am able to conclude with certainty that the fingerprints found in the LDW represent Monsanto's Aroclors and that non-Aroclor PCB sources in the LDW are negligible (i.e. less than about 5% in most media).

Non-Aroclor PCB congeners

Several PCB congeners are known to be associated with non-Aroclor sources. The congeners known to arise only from non-Aroclor sources are PCBs 11 (probably from pigments) and 68 (from silicone rubber). PCB 11 is virtually absent in Monsanto's Aroclors, but has been shown to be produced inadvertently during the synthesis of some organic pigments (King et al., 2002; Litten et al., 2002; Hu and Hornbuckle, 2009; Rodenburg et al., 2010b). As a result, PCB 11 is present in various consumer products that have printed designs on them or their packaging (Rodenburg et al., 2010b; Guo et al., 2014; Stone, 2014; City of Spokane Wastewater Management Department, 2015; Rodenburg et al., 2015b), and can be released from these products into environmental compartments including air, storm water, surface water, sediment, and fish tissue (King et al., 2002; Litten et al., 2002; Choi et al., 2008; Du et al., 2008; Du et al., 2009; Rodenburg et al., 2010b; Rodenburg et al., 2011; Praipipat et al., 2013; Rodenburg et al., 2015a; Rodenburg and Ralston, 2017).

PCB 68 is also virtually absent in Monsanto's Aroclors but is present in silicone rubber that used 2,4-dichlorobenzoyl peroxide as a curing agent (Perdih and Jan, 1994; Anezaki and Nakano, 2015; Herkert et al., 2018). As a result, it can be present in environmental samples as an artifact (contamination) when silicone rubber tubing is used to collect the sample (Greyell and Williston, 2018). Herkert et al. (2018) have argued that PCB 68 can be present in polyester resins which have been cured using 2,4-dichlorobenzoyl peroxide. Use of 2,4-dichlorobenzoyl peroxide is typically associated with PCBs 44+47+65 and 45+51 along with PCB 68. Unfortunately, 44+47+65 and 45+51 are also found in Monsanto's Aroclors (Rushneck et al., 2004), and they can also be markers for dechlorination of Monsanto's Aroclor PCBs by bacteria (Bedard and May, 1996; Magar et al., 2005; Bedard et al., 2006; Bzdusek et al., 2006a; Fagervold et al., 2007; Rodenburg et al., 2010a).

Other congeners are sometimes associated with non-Aroclor sources. PCBs 206, 208, and 209 can be produced during the synthesis of some organic (Hu and Hornbuckle, 2009) and inorganic pigments (Gamboa et al., 1999; Du et al., 2008; Praipipat et al., 2013; Rodenburg and Ralston, 2017). Although these three congeners are mostly absent in the five main Aroclors (1016, 1242, 1248, 1254, and 1260), comprising a maximum of 0.9% of PCBs in Monsanto's Aroclor

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1260, they are present in some of the rare Aroclors. In Monsanto's Aroclor 1268, they comprise 51% of total PCBs (Rushneck et al., 2004). PCB 209 was reportedly present in Monsanto's Aroclors 1270 and 1271 (Hermanson et al., 2016), although Rushneck et al. (2004) did not measure the congener fingerprints of these Monsanto's Aroclors. In some locations, PCB 209 is clearly associated with commercial PCB production. For example, PCB 209 was found to be the dominant congener in some samples of soil, tree bark, and house dust collected near the former Monsanto PCB manufacturing facility in Sauget, IL (Stratton and Sosebee, 1976; Gonzalez et al., 2011; Hermanson et al., 2016). In contrast, in some places, the presence of PCB 209 is clearly associated with pigments. For example, in one of the rivers I have investigated, a PMF-generated factor dominated by PCBs 206, 208, and 209 comprises 61% of the PCB mass in the sediment (Praipipat et al., 2013) and we are reasonably certain that it arose primarily from a facility that manufactured titanium dioxide via a process that is known to produce PCBs (Gamboa et al., 1999).

A variety of PCB congeners that occur in the Monsanto's Aroclors are also sometimes found in non-Aroclor sources such as pigments. For example, Hu and Hornbuckle (2009) identified 47 peaks containing 67 PCB congeners in commercial paint pigments. Note that this does not necessarily imply that all 67 congeners were present in the pigments. When congeners coelute (such as, for example, the coeluting group of PCBs 86+87+97+109+125) it is possible that only one of the congeners is actually contained in the pigment. Nevertheless, in these pigments, Hu and Hornbuckle (2009) found congeners such as PCB 52, which is present in all of Monsanto's Aroclors tested by Rushneck et al. (2004) and is most abundant in Monsanto's Aroclor 1248, where it constitutes about 7.1% by weight.

Non-commercial fingerprints from other data sets

The approach of using PMF2 analysis to identify PCB sources has been used in many previous studies that can be used to estimate the minimum contribution of non-commercial PCB sources that can be detected using the PMF approach. Table 1 summarizes the contribution of non-commercial PCB sources to various data sets investigated by the author of this report. In all cases, fingerprints identified in these studies as 'non-commercial' met the criteria enumerated above.

Table 2 suggests that the PMF analysis approach is capable of detecting a non-commercial fingerprint when it contributes as little as 1.1% of the PCB mass in the data set. To the extent that the data set is representative of the compartment (water, sediment) as a whole, this percentage can be interpreted as the contribution of the non-commercial source to all the PCB sources for that compartment. In five of the sixteen cases in which a non-commercial PCB factor was identified, the contribution of the non-commercial factor was equal to or less than 2%, suggesting that this approach can routinely identify contributions at this level.

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For the present analysis, we conclude that for compartments in which a non-commercial factor was not isolated by the PMF analysis, the contribution of non-commercial PCBs to that compartment is 2% or less with a reasonable degree of certainty.

Table 1: Non-commercial PCB factors isolated in other studies and their contribution to the mass in the data set.

Location	Matrix	Contribution of factor associated with:		Reference
		PCB 11	PCB 209	
River A	Water	5%	19%	(Du et al., 2008)
	Sediment	1.4%	61%	(Praipipat et al., 2013)
	permitted discharges*	6.7%	1.5%	(Rodenburg et al., 2010a)
Harbor	Water	2.4%	none	(Rodenburg et al., 2011)
Superfund Site	Water	6.3%	none	(Rodenburg et al., 2015c)
	sediment	1.1%	none	
River B	atmospheric deposition	9%	4%	(Rodenburg and Leidos, 2017a)
	sediment	1.5%	none	
	stormwater solids	2%	8%	
	stormwater	4%	6%	
River C	Water	8-15%	none	(Rodenburg et al., 2020)

*For permitted discharges, the contribution represents the contribution to the total *load* of PCBs discharged from all facilities in the data set to the river. Load is calculated as concentration times flow, so facilities with larger flows will represent a larger contribution to the total load.

Results

Summary of results from previous Green-Duwamish River study

Air deposition

Summary: In samples of air deposition from near the LDW, at least 87% of the PCBs arise from Monsanto's Aroclors. This is a conservative estimate because one of the six factors isolated from the PMF analysis is a mixture of Aroclor and non-Aroclor PCBs, but is here completely ascribed to non-Aroclor sources. Also, one of the six factors that did not represent Monsanto's Aroclors might result from blank contamination. This work resulted in a peer-reviewed publication (Rodenburg et al., 2019).

Factors: Six factors were isolated from the PMF analysis of the air deposition data (64 samples, 64 peaks). In the GD reports, these factors were referred to as Air1 through Air6. Four of these factors (Air1, Air2, Air5, and Air6) resemble the four main Aroclors produced by Monsanto (1242, 1248, 1254, and 1260) and two factors (Air3 and Air4) are not similar to any of Monsanto's Aroclors. These two factors contain non-Aroclor congeners such as PCB-11 (Air3) and PCB-209 (Air4). Air3 is dominated by PCB-11 (29 percent of the fingerprint). When PCB-11 is excluded from the correlation, the remainder of Air3 resembles Monsanto's Aroclor 1254 (R^2 = 0.72), but this is probably not very meaningful because Air3 also contains other congeners that are not present in Monsanto's Aroclor 1254. The comparison of the Air3 with the iPCB source fingerprints found several with R^2 values greater than 0.4, which was expected, since this is thought to represent a non-Aroclor source. Comparison of the other air deposition PMF factors with the iPCB source fingerprints did not yield any meaningful matches.

Like Air3, Air4 does not resemble any of Monsanto's Aroclors and includes several non-Aroclor congeners. Since the analysis of the Green-Duwamish data, I have become more aware of the uses of low-production-volume Aroclors, such as the use of Monsanto's Aroclor 1268 in a building material called Galbestos (Erickson and Kaley, 2011). In light of this, I compared Air4 with the low-production Aroclors, and found some similarity (figure 1). The best fit for Air4 is a combination of 41% Monsanto's Aroclor 1232, 23% Monsanto's Aroclor 1254, and 36% Monsanto's Aroclor 1262, yielding an R^2 value of 0.59. Thus, there is some reason to believe that this factor might be related to Monsanto's Aroclors, but also clearly contains some inadvertent congeners such as PCB 11.
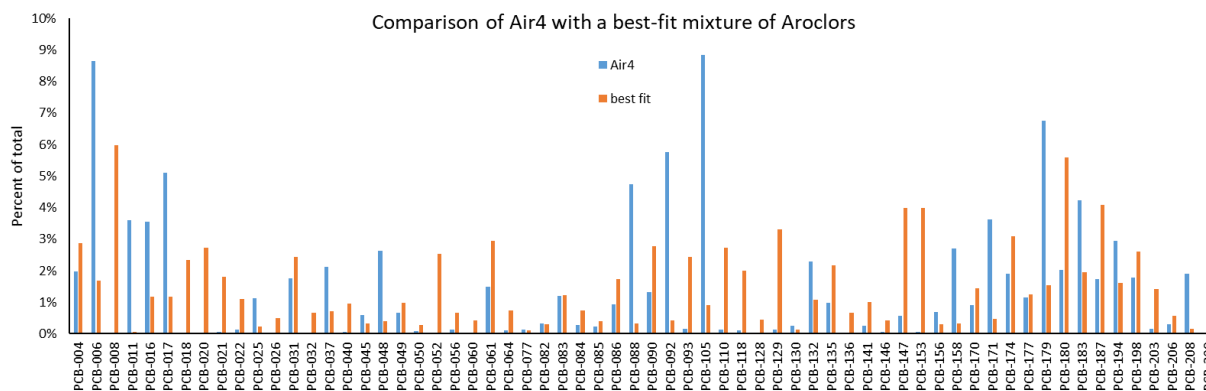

Figure 1. Comparison of the fingerprints of Air4 with a best-fit mixture of Monsanto's Aroclors. The best fit is a combination of 41% Monsanto's Aroclor 1232, 23% Aoclor 1254, and 36% Monsanto's Aroclor 1262, yielding an R2 value of 0.59.

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Samples: Of the 64 samples included in the PMF model, 40 were from stations in the LDW: 7 from Beacon Hill, 12 from Duwamish/Diagonal (one of which was analyzed in duplicate, yielding 13 total samples), 15 from South Park, and 5 from Georgetown.

Abundance: For these samples, the main source of PCBs was Air1, explaining 29% of the PCB mass, followed by Air2 (24%), Air6 (21%), Air5 (13%), Air3 (10%) and Air4 (3%). Thus, the two factors (Air3 and Air4) that contain some non-Aroclor PCBs comprise about 13% of the PCBs in the air deposition samples collected in the LDW. As noted above, some fraction of this 13% might be due to Monsanto's Aroclors.

Sediment

Summary: In LDW sediment, PCBs arise almost exclusively (>99%) from Monsanto's Aroclors.

Factors: Five factors were isolated from the PMF analysis of the sediment data (146 samples, 80 peaks). In the original GD report, these factors were identified as Sed1 through Sed5. Three of these factors were very similar to Monsanto's Aroclors: Sed2 was similar to Monsanto's Aroclor 1248 (R^2 = 0.84), Sed3 was similar to Monsanto's Aroclor 1254 (R^2 = 0.94) and Sed5 was similar to Monsanto's Aroclor 1260 (R^2 = 0.99).   Sed1 was similar to Monsanto's Aroclor 1016 with an R^2 value of 0.42. It is best described as a mixture of 36% Aroclor 1016, 21% Aroclor 1248, and 42.5% Aroclor 1260, with an R^2 value of 0.75. PCB 11 comprised 4% of Sed4, suggesting that this fingerprint might be related to inadvertent PCB sources. In light of my new awareness of the uses of low-production-volume Monsanto's Aroclors, I compared Sed4 to a mix of Monsanto's Aroclors including 1268 and found that it is similar to a mixture of 88% Aroclor 1260 and 12% Aroclor 1268 (R^2 = 0.59). This mixture of Monsanto's Aroclors cannot explain the abundance of PCB 11 in Sed4, but it does explain much of the higher molecular weight PCBs in this fingerprint, and suggests that at least part of the fingerprint comes from Monsanto's Aroclors. Comparison of the sediment PMF factors with the iPCB source fingerprints did not yield any matches with R^2 values greater than 0.4.

Samples: Of the 146 samples of sediment analyzed in the PMF model, 24 are in the LDW. Of these, 6 are in the LDW (i.e. between RM 0.7 and 5), while the remaining 18 are in the Harbor Island area. Of these 18, four (sample codes 3107, 3108, 3109, and 3110) were not provided with latitude and longitude coordinates, but are believed to be in the Harbor Island area because they bear the same label ("East and West") as the other Harbor Island samples.

Abundance: Sed5 (1260) was the dominant PCB source and explained 58% of the PCB mass in the samples from the area considered in this case. Sed2 (1248) and Sed3 (1254) explained 15% and 19% of the mass, respectively. Sed1 explained 8% of the mass. Taken together, these four factors which resemble Monsanto's Aroclors, explain 99.6% of the mass in the sediment. Sed4, which contains PCBs from both Monsanto's Aroclors and inadvertent sources, explains just 0.4% of the PCB mass in the area considered in this case.

Surface water

Summary: The PCBs in the surface water of the LDW arise almost exclusively (>99%) from Monsanto's Aroclors.

Factors: Four factors were identified from the surface water data set (201 samples and 42 peaks) denoted factors Water1 through Water4 in the GD reports. As noted in the GD report, the number of non-detects in the surface water samples made it necessary to limit the data set to a relatively low number of peaks, and inadvertent PCBs were excluded from the PMF input for this reason. In addition, contamination of some samples from the Green River (which is not part of the LDW) with PCBs 44+47+65 and 45+51 was caused by the use of silicone rubber tubing for sampling. These congeners were therefore excluded from the PMF input. Due to the limited congener list, the PMF solution had no chance of identifying inadvertent PCB factor(s). Therefore, it is no surprise that comparison of the surface water PMF factors with the iPCB source fingerprints did not yield any meaningful matches. The four factors that were isolated by the PMF program therefore all resembled Monsanto's Aroclors. Because PCBs 11 and 206+208+209 were not included in the PMF model, the only way to assess their importance was to compare their abundance with the PMF solution. The PMF model is still necessary, however, to confirm that the other congeners were present in patterns that match Monsanto's Aroclors. While the GD reports noted that "no conclusions can be drawn about sources of PCBs to the water of the LDW" from that original analysis, new data that has become available since the original GD reports and analyzed below lends much more certainty to the conclusion that Monsanto's Aroclors are the dominant sources of PCB to the water column of the LDW.

Samples: Of the 201 samples of surface water, 60 were from the Harbor Island Area and 10 were from RM 3.3, within the LDW.

Abundance: Figure 3-10 of the GD report shows the proportions of PCBs due to PCB 11 and 206+208+209 in at RM 0 (Harbor Island) and RM 3.3 (within the LDW). At these locations, the contribution from these inadvertent congeners was calculated to be 0.4% at RM 0 and 0.2% at RM 3.3. PCBs 44+47+65 and 45+51 were deliberately excluded from this analysis because they might have arisen from the silicone rubber contamination that plagued the Green River samples. However, there is no evidence that silicone rubber contaminated the samples from the LDW. In the samples from the LDW, these congeners comprised a total of 3.3% of the sum of all detected PCBs, an amount that is in line with what would be expected from these congeners if they arose from Monsanto's Aroclor 1248, which was abundant in the LDW. Therefore, the total contribution of inadvertent PCBs in the LDW is less than about 1%.

Six samples from Harbor Island were not included in the PMF input because less than 20 peaks were detected in them, i.e. their PCB levels were extremely low.

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Tissue

Summary: In the tissues of organisms from the LDW, PCBs arise almost exclusively (>99%) from Monsanto's Aroclors.

Factors: Five factors were identified by the PMF model (90 peaks in 128 samples), denoted Tissue1 through Tissue5 in the GD reports. Given the ADME (absorption, distribution, metabolism and excretion) processes that affect PCBs in living tissue, the congener profiles obtained from tissue are expected to be less similar to the parent Aroclors than the fingerprints obtained from other media, such as water or sediment. Even though most of the typical inadvertent congeners, including PCBs 11, 206, 208, and 209, were included in the PMF model, all five of the isolated factors were similar to Monsanto's Aroclors, with R^2 values ranging from 0.43 to 0.84. Where the fingerprints differed from the Monsanto's Aroclors, the differences can be explained by metabolism of some congeners. Therefore, the PMF model generated no evidence that would suggest that inadvertent PCBs are important in the tissues of organisms in the LDW. Comparison of the tissue PMF factors with the iPCB source fingerprints did not yield any matches with R^2 values greater than 0.4.

Samples: Of the 128 samples included in the PMF input, all were obtained from the LDW.

Abundance: None of the PMF-generated fingerprints was dominated by inadvertent congeners or otherwise showed any evidence that it was indicative of inadvertent PCB sources. The sum of PCBs 11, 206, 208, and 209 averaged 0.2% of total PCBs in the tissue samples. Therefore, inadvertent PCB sources were negligible in the tissue samples.

Storm drains

Summary: In the storm drain solids and storm water samples from stormwater drainage pipes connected to the LDW, PCBs arise overwhelmingly (>95%) from Monsanto's Aroclors.

Factors: Six factors were isolated from the PMF analysis, denoted Storm1 through Storm6 in the GD reports. Four of these were identified in the original GD report as being extremely similar to Monsanto's Aroclors 1016, 1248, 1254, and 1260 with R^2 values ranging from 0.86 to 0.98. Storm6 was described in the original GD report as being "not similar to any Aroclor." However, comparison of this fingerprint with the low-production volume Aroclors demonstrates that it is reasonably well described as a mixture of 24% 1248, 33% 1254, 15% 1262, and 28% 1268 (Figure 2). None of the obvious inadvertent congeners (PCBs 11, 206, 208, or 209) are abundant in this fingerprint. The congeners that are abundant in the fingerprint are also present in the four Aroclors that explain much of its variation, suggesting that any differences between Storm6 and the Monsanto's Aroclors are due to weathering processes. Therefore, Storm6 represents Monsanto's Aroclors and not inadvertent PCBs. Comparison of the storm drain PMF factors with the iPCB source fingerprints did not yield any meaningful matches.
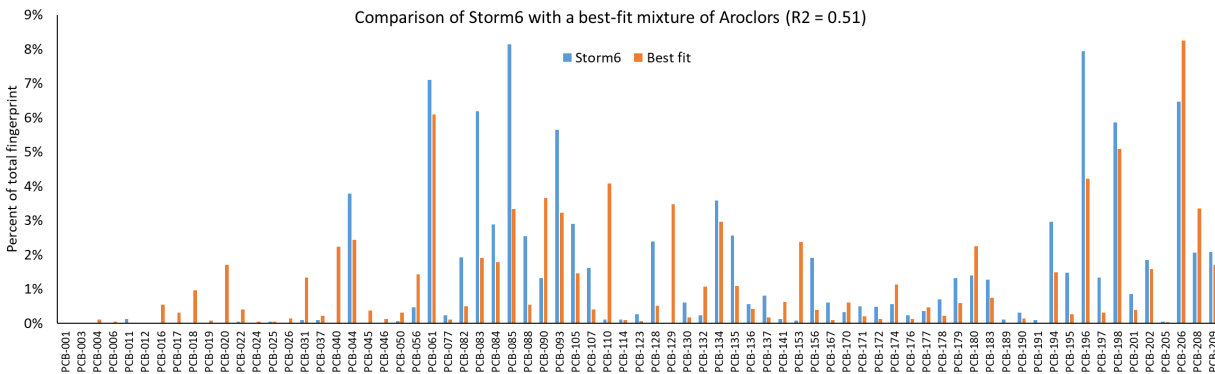
Figure 2. Comparison of Storm6 with a best-fit mixture of Monsanto's Aroclors. The best fit mixture is comprised of 24% 1248, 33% 1254, 15% 1262, and 28% 1268.

Storm3 contained a high proportion of PCB 11 (13%), but the remainder of this fingerprint resembled Monsanto's Aroclor 1260 (R^2 = 0.78). Thus, part of this fingerprint is attributable to inadvertent PCBs and part arises from Monsanto's Aroclors.

Storm6, which contained the low-production volume Aroclors, is most abundant in samples collected near and downhill from the North Boeing Field/Georgetown Steam Plant Site. Monsanto's Aroclors 1262 and 1268 were detected in samples collected at this Site (Leidos, 2013). Galbestos building material was found at this site (Leidos, 2013). Monsanto's Aroclor 1268 was the main PCB formulation used in Galbestos (Erickson and Kaley, 2011). In addition, Boeing purchased some Aroclor 1268 in 1963 (Exhibit 13 to the Deposition of Dr. Robert Kaley in *City of Seattle v. Monsanto*, *Seattle Sales Summaries Analysis*, p. 2).

Samples: The storm drain PMF input included samples of both storm drain solids (34 samples) and storm water (40 samples). All of the 74 samples included in the PMF input are considered to be in the LDW. Although some appear to be on the borderline of the city, they drain into the river within the LDW. One sample was not included in the PMF input because very few peaks were detected in it.

Abundance: the fingerprint containing a high proportion of PCB 11 (Storm3) explains 2% of the mass of PCBs in the storm drain solids and 4% of the mass in the storm water. Since only part of Storm3 is attributable to inadvertent PCBs, the actual contribution of inadvertent PCBs to the stormwater and storm drain solids is less than this.

Otter scat

Summary: In otter scat gathered on the banks of the LDW, PCBs arise overwhelmingly (99%) from Monsanto's Aroclors.

Factors: Six factors were isolated by the PMF analysis from the otter scat data set (73 peaks in 74 samples), denoted Scat1 through Scat6 in the GD reports. As with the samples of organism tissue, PCBs in the otter scat samples have undergone extensive ADME, causing some of the fingerprints to be quite different from Monsanto's Aroclors. Nevertheless, the differences between the PCB fingerprints found in the otter scat and Monsanto's Aroclors can be explained by the metabolism of some congeners. As a result, all six of the otter scat factors can be attributed to Monsanto's Aroclors. This is true even though PCBs 11, 206, 208, and 209 were included in the PMF input. Comparison of the otter scat PMF factors with the iPCB source fingerprints did not yield any matches with R^2 values greater than 0.4.

Samples: Of the 73 samples included in the PMF input, 28 were collected within the LDW at the following sites: Harbor Island (RM 0), South Park Marina (RM 3.5) and Hamm Creek (RM 4.5).

Abundance: Since none of the PMF derived factors arose from inadvertent sources, such sources are not significant in the otter scat. The sum of PCBs 11+206+208+209 constituted on average 1.0% of the PCBs in the otter scat samples from the LDW.

Groundwater

Summary: In samples of groundwater that drains into the LDW, Monsanto's Aroclors are virtually the only source of PCBs. The PMF program does not identify a factor related to inadvertent PCBs.

Factors: Four factors were isolated from the PMF analysis of the groundwater data (58 peaks in 44 samples), denoted GW1 through GW4 in the GD reports. Because a relatively small number of samples were available for analysis, the PMF input was limited to 58 peaks which comprised 76% of the total PCB mass detected in these samples. PCB 11 was included in the PMF input, but PCBs 206, 208, and 209 were not. Comparison of the groundwater PMF factors with the iPCB source fingerprints did not yield any meaningful matches.

Samples: Of the 44 samples included in the PMF input, all were collected in areas that drain into the LDW. Six samples of groundwater were excluded from the PMF input because less than 10 peaks were detected in them.

Abundance: The fact that none of the four factors isolated from the PMF analysis was related to inadvertent sources suggests that such sources are not important in the groundwater samples. However, since about 24% of the PCB mass was excluded from the PMF input, I examined the raw data to investigate the abundance of inadvertent congeners. PCBs 11+206+208+209 comprised high proportions (up to 31% with non-detects set to zero) of total PCBs in some of the samples with the lowest concentrations. For all groundwater samples with total PCB concentrations above 2 ng/L, the contribution of these four congeners was always

below 0.4% of total (non-detects set to zero). Thus, inadvertent PCB are negligible in terms of the load of PCBs delivered to the LDW by groundwater.

Summary of results from new data sets

The new data was obtained from the Lower Duwamish Waterway Group (LDWG) online project library at https://ldwg.org/project-library/. The website contained significant amounts of new data regarding surface water and smaller amounts of data on sediment, sediment pore water, and fish.

Surface Water

The new Duwamish River data included 35 passive samples (collected between 9/25/17 and 8/29/18) and grab samples collected using a Niskin sampler (44 samples) or an unspecified sampler (4 samples) between 8/28/17 and 7/30/18. Two of the passive samples and none of the grab samples contained detectable levels of PCB 11. In these samples, PCB 11 contributed about 0.2% of the sum of PCBs. Similarly, PCBs 68 and 209, which are often associated with non-Aroclor sources, averaged less than 0.35% of total PCBs.

These samples were using PMF by combining them with the previous data set of 201 samples of water analyzed in the Green-Duwamish study, in which 42 PCB peaks were included in the PMF input. This is a relatively small number of peaks which was necessitated by the many non-detects in the water data set. Notably, the passive samples had far fewer non-detects. The new data was therefore analyzed three ways.

First, the new data was analyzed via PMF by adding the new data to the older data set. the PMF data set of 42 peaks in 284 samples gave a solution virtually identical to that originally obtained from the 42 peaks/201 sample data set analyzed in the original Green-Duwamish project. In both cases, the optimal solution contained four factors (source terms) and their congener patterns were similar between the two data sets (R^2 values ranging from 0.911 to 0.997). Once again, comparison of the new surface water PMF factors with the iPCB source fingerprints did not yield any meaningful matches. This suggests that there has been no substantial change in the types of PCB sources to the Duwamish River surface water between the original Green-Duwamish project and 2018.

Second, the passive samples were each compared to the iPCB fingerprints. Comparison of the passive surface water samples with the iPCB source fingerprints did not yield any matches with R^2 values greater than 0.4.

Third, the passive samples were compared to the Monsanto's Aroclors via Multiple Linear Regression (MLR), sometimes also called Partial Least Squares (PLS) regression. I compared the PCB congener fingerprints in the passive samples with those in Monsanto's Aroclors as measured by Rushneck et al. (2004) on an SPB-octyl gas chromatography column. This

technique conducts a MLR of the congener fingerprint of the sample (y) versus Monsanto's Aroclor fingerprints (x's). A multiple linear regression was performed in which a congener pattern was calculated that represented a linear combination of the five main Aroclors produced by Monsanto:

$$C_f = aC_{1016} + bC_{1242} + cC_{1248} + dC_{1254} + eC_{1260} \hspace{3cm} (4)$$

where

C = concentration of the resolved factor (f) or individual Aroclor,

a, b, c, d and e = partial regression coefficients.

This approach follows the scheme outlined by Burkhard and Weininger (1987) and more recently by Zhang and Harrington (2015). This approach has been widely used to determine PCB sources (Swackhamer and Armstrong, 1988; Verbrugge et al., 1991). MLR was conducted using R version 4.0.3 in R Studio version 1.3.1093 using the nnls (non-negative least squares) package. Congener fingerprints were normalized such as that each congener/peak was expressed as a percent of the total fingerprint, with the sum of all congeners equal to 100%. For purposes of MLR, non-detects were set to zero, because in their measurements of the fingerprints of Monsanto's Aroclors performed by Rushneck et al. (2004) via method 1668 and by Frame (1997) and Frame et al. (1996), non-detects were likewise set to zero and no information about detection limits was available.

All of the passive samples strongly resembled a mix of Monsanto's Aroclors with R^2 values ranging from 0.91 to 0.95 (p << 0.05). This indicates that the samples consist primarily of unweathered Monsanto's Aroclors. This information, combined with the low abundance of non-Aroclor congeners noted above leads me to conclude that non-Aroclor PCBs continue to contribute less than 1% of PCBs in the surface water of the Duwamish River.

The GD reports note that due to the limited number of samples and large number of non-detects in the original water data set, "no conclusions can be drawn about sources of PCBs to the water of the LDW" from that original analysis. The addition of a large number of new water samples allowed me to re-analyze this new larger data set, and the results of that re-analysis allow me to reach the conclusion that Monsanto's Aroclors are the main source of PCBs to the LDW. In addition, the new passive samples allowed me to use MLR to analyze congener patterns in the water column, bolstering the conclusion that the sources of PCBs to the surface water are predominantly Monsanto's Aroclors, because they have very few non-detect values and were deployed in the river for one month. This long deployment period means that they represent all of the PCB sources to the river over that one-month period, in contrast to grab samples, which represent a single time point.

Sediment

Twelve samples of sediment were collected during February and March of 2018. In these samples, congeners such as PCBs 11, 68, and 209 were never more than 0.55% of total PCBs. Visually, these samples resembled others from the original Green-Duwamish project. MLR analysis of these samples yielded R^2 values between 0.95 and 0.98. This information, combined with the low abundance of non-Aroclor congeners noted above leads me to conclude that non-Aroclor PCBs continue to contribute less than 1% of PCBs in the sediment of the Duwamish River.

Pore Water

Pore water was sampled using passive Solid Phase MicroExtraction (SPME) devices in April of 2018. Eleven samples were collected. In these samples, congeners such as PCBs 11, 68, and 209 were never more than 0.1% of total PCBs. This data was analyzed using MLR. All samples yielded R^2 values between 0.90 and 0.95. This information, combined with the low abundance of non-Aroclor congeners noted above leads me to conclude that non-Aroclor PCBs continue to contribute less than 1% of PCBs in the sediment of the Duwamish River.

Seeps

One sample of PCBs from a seep at South Park Marina was analyzed for PCB congeners. PCBs 11, 68, and 209 were less than 0.1% of total PCBs. MLR of this sample shows that it is similar to Monsanto's Aroclors (R^2 = 0.84).

I reserve the right to amend my opinion based on new information regarding the Lower Duwamish Waterway.

I hereby declare that the above statement is true to the best of my knowledge and belief, and that I understand it is made for use as evidence in court and is subject to penalty for perjury.

Date: 11/19/2021 _____   _____

Lisa A. Rodenburg, PhD

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Rodenburg, L.A., Du, S., Xiao, B., Fennell, D.E., 2011. Source Apportionment of Polychlorinated Biphenyls in the New York/New Jersey Harbor. Chemosphere 83, 792–798.

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Swackhamer, D.L., Armstrong, D.E., 1988. HORIZONTAL AND VERTICAL-DISTRIBUTION OF PCBS IN SOUTHERN LAKE-MICHIGAN SEDIMENTS AND THE EFFECT OF WAUKEGAN HARBOR AS A POINT-SOURCE. J. Gt. Lakes Res. 14, 277-290.

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Uchimiya, M., Arai, M., Takeda, S., Hosono, S., Masunaga, S., 2011. Deciphering localized dioxins and PCBs contamination in Japanese sediments using Positive Matrix Factorization. Abstracts of Papers of the American Chemical Society 242.

Verbrugge, D.A., Othoudt, R.A., Grzyb, K.R., Hoke, R.A., Drake, J.B., Giesy, J.P., Anderson, D., 1991. CONCENTRATIONS OF INORGANIC AND ORGANIC CONTAMINANTS IN SEDIMENTS OF 6 HARBORS ON THE NORTH-AMERICAN GREAT-LAKES. Chemosphere 22, 809-820.

Zhang, M.L., Harrington, P.D., 2015. Simultaneous quantification of Aroclor mixtures in soil samples by gas chromatography/mass spectrometry with solid phase microextraction using partial least-squares regression. Chemosphere 118, 187-193.

CURRICULUM VITAE

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EDUCATION

Ph.D. 1999, The Johns Hopkins University, Dept of Geography and Environmental Engineering
B.A. 1991, Wittenberg University, Springfield, OH, Chemistry

PROFESSIONAL EXPERIENCE

2020-present Associate Chair, Rutgers Department of Environmental Sciences
2017-present Professor, Rutgers University, Department of Environmental Sciences
2018-present Graduate program director, Environmental Science
2012-2018   Undergraduate Program Director, Environmental Science (~140 students)
2010-2017   Associate Professor, Rutgers University, Department of Environmental Sciences
2004-2010   Assistant Professor, Rutgers University, Department of Environmental Sciences
2002-2004   Assistant Research Professor, Rutgers University, Department of Environmental Sciences
2001-2002   Laboratory Researcher I, Rutgers University, Department of Environmental Sciences
1998-2001   Camille and Henry Dreyfus Post-Doctoral Fellow in Environmental Chemistry, Rutgers University, Department of Environmental Sciences
1991-1993   Quality Assurance Chemist, Hoechst-Roussel Pharmaceuticals Inc., Somerville, NJ

RESEARCH INTERESTS

Fate of anthropogenic chemicals, particularly PCBs and other semivolatile organic contaminants (SOCs), in water, air, sediments, and biota. Source apportionment of contaminants, management and analysis of large data sets.

HONORS AND AWARDS

Excellence in Review Award from *Environmental Science and Technology* 2014
Camille and Henry Dreyfus Foundation Post-Doctoral Fellowship in Environmental Chemistry
ACS Environmental Division Graduate Student Paper Award 1998
ACS Environmental Division Graduate Student Award 1998
Graduate Student Fellowship, National Science Foundation, 1994-1997
Dean's Fellowship, Johns Hopkins University, Whiting School of Engineering, 1993, 1998
National Merit Scholar, 1987-1991
Graduated Summa Cum Laude from Wittenberg University

PROFESSIONAL AFFILIATIONS

American Chemical Society, Environmental Chemistry Division (ACS)

Society of Environmental Toxicology and Chemistry (SETAC)
Association of Environmental Engineering and Science Professors (AEESP)
Association for Women in Science (AWIS)
Environmental Sciences Affiliate of the New York Academy of Sciences

EDUCATIONAL ACTIVITIES
Primary teaching (* courses created or totally redesigned)

2019-present	16:375:501 Environmental Science Analysis*	Instructor
2015-2017	11:375:197 *Environmental Science Literacy** (house course for the Environmental Science LLC, Douglass Project for women in STEM)	Instructor
2011- present	11:375:340 Environmental Applications of Organic Chemistry*	Instructor
2001- 2013	11:375:310 Analytical Environmental Chemistry Laboratory*	Instructor
2000 - present	16:375:522 Environmental Organic Chemistry*	Instructor

Other teaching

2010-present	01:556:130 Introduction to Scientific Research (ISR)	Research mentor
2012	11:015:103 Portals to Academic Study Success	Instructor
2010-2011	11:375:432 *Readings in Environmental Science** (house course for the Douglass Project for women in STEM)	Co-instructor (50%)
2009	16:375:540 Atmospheric Chemistry*	Instructor
2007	11:375:423/523 Environmental Fate And Transport	Co-instructor (50%)
2006	375:454 Soil Biological Processes, cross-listed with 375:573 Soil Ecosystem Processes	Co-instructor (40%)
2005 – 2006	01:160:200 Introduction to Research in Chemistry	Research mentor
1998	Chemistry of Environmental Issues (John Hopkins University)	Teaching assistant

Curriculum development
2016 As Undergraduate Program Director (UPD), redesigned the undergraduate Environmental Sciences curriculum
2020 As Graduate Program Director, redesigned the graduate Environmental Sciences curriculum and created a 4+1 BS/MS program.

MEDIA COVERAGE
ABC News Good Morning America: Is the Color Yellow Dangerous? (interview about PCBs in pigments). 2/23/2014
Scientific American: "Yellow Pigments in Clothing and Paper Contain Long-Banned Chemical" 2/20/2014
Yahoo.com: "PCBs banned for decades but still lurking in some yellow products" 2/25/2014
Newsmax.com "Many Yellow Items Still Contain Banned PCB Chemical, Study Says." 2/21/2014
Environmental Health News: "Yellow pigments in clothing, paper contain long-banned PCB." 2/20/2014
Food Packaging Forum: "PCB-11 detected in clothing and paper samples." 2/21/2014

Environmental Health Perspectives: "Nonlegacy PCBs: Pigment Manufacturing By-Products Get a Second Look." Volume 121, Issue 3, Pages A87-A93. March 2013.

IMPACTS
The State of Washington in 2013 passed legislation (bill 6086) that requires the state to purchase only products that do not contain PCBs. This legislation is aimed in large part at PCBs in pigments, and my work in this area raised awareness and indirectly led to this legislation.

SERVICE
Mentoring
Participating in the Rutgers Connection Network (RCN) mentoring program since its inception in 2015. Mentored Jenny Carleo (Extension Agent), Lisa Bono (post-doc), Christina Bergy (Assistant Professor, Genetics), Neda Bolourchi (post-doc)
Mentoring committee member for Benjamin Lintner (Assistant Professor) and Jeffra Schaefer (Assistant Research Professor) in the Department of Environmental Science, Rutgers
Founder, *Beautiful Untenured Female Faculty* (BUFF), a peer-to-peer networking group for female faculty at SEBS
Working with High School students on various projects for science fairs, including the Partners in Science program (Liberty Science Center); North Jersey Regional Science Fair; a competition at Monmouth University; and the Young Science Achievers Program. Eleven students mentored so far (2006-present)
Mentored nearly 100 undergraduate interns

Professional Societies
Session Chair (with Kristie Ellickson). "Environmental Data Mining - Doing Research With No Money." SETAC North America Annual Meeting, November 2017, Minneapolis, MN.
Session Chair (with Nicole Fahrenfeld). "Advances in Understanding PPCP Fate in Wastewater Collection & Treatment Systems." American Chemical Society 252nd National Meeting, August 21-25, 2016, Philadelphia, PA.
Member of the 2005 SETAC North America Annual Meeting Program Committee
Session Chair (with Miriam Diamond). "Urban Contaminants: Sources, Composition, Fate from a Multimedia Perspective." SETAC North America 28th Annual Meeting, November 11-15, 2007, Milwaukee, WI.
Session Chair (with DE Fennell) "Fate of Persistent Organic Pollutants in Urban Systems." Division of Environmental Chemistry, 234th American Chemical Society (ACS) National Meeting, August 19-23, 2007, Boston, MA.
Poster session organizer, Gordon Conference on Environmental Sciences: Water, 2000.

University
Associate Chair, Department of Environmental Science, 2020-present
Provost's COACHE Working Group, 2020-present
Department Representative: SEBS Faculty Diversity Advocate, 2020-present
Graduate Director Program, Environmental Science, 2018-present
Department of Environmental Sciences, Equipment Committee, 2014-present

Search committee, TT appointment in Environmental Microbiology, 2015-2016
Strategic Planning Committee for Douglass Residential College, 2015
Douglass Project STEM Summer Stipend selection committee, 2015
Undergraduate Program Director, Environmental Sciences, 2012-2018
Graduate Program in Environmental Sciences, Admissions Committee, 2012-2015
New Brunswick Faculty Council, 2009-2012
Search committee, broad faculty announcement in Environmental Sciences, 2008-2010
Chair, Environmental Sciences Graduate Program Curriculum Committee, 2006-2009
Department of Environmental Sciences Space Committee, 2006-2009
Dean's Ad-Hoc Committee on Childcare, 2005

Panels
Member, Interstate Technology and Regulatory Council's (ITRC) Environmental Data
        Management Best Practices Team. 2021-present
Member, Science and Technical Advisory Committee (STAC), New York/New Jersey Harbor &
        Estuary Program. 2017-present
Science Advisor, *Made Safe* (http://madesafe.org/), part of *Non-Toxic Certified*, 2015-present
Reviewer - Green-Duwamish River Watershed PCB Congener Study: Phase 1, 2015
Advisor to the Spokane River Regional Toxics Taskforce, Spokane, WA, 2012-present
Served as an expert witness for the State of Washington (Department of Ecology) at the August
        2012 meeting of the Environmental Council of States. I presented a short lecture on the
        problem of inadvertent production of PCBs in pigments.
Member of Expert Panel advising the Delaware River Basin Commission on establishment of a
        TMDL for PCBs in the Delaware River 2001-2009

Other
Proposal reviewer for the Hudson River Foundation: Hudson River Fund and Mark Bain
        Graduate Fellowships
Reviewer for the Arctic Monitoring and Assessment Programme (AMAP) review of Non-
        Aroclor and Byproduct PCBs 2016
Faculty Advisor, Futurology Club, 2015-2016
Author of Wikipedia entry on Diarylide Pigment
Proposal reviewer, National Science Foundation, Petroleum Research Fund, and U.S. Civilian
        Research and Development Foundation (CRDF).
Reviewer for Environmental Science and Technology, Atmospheric Environment,
        Environmental Engineering and Science, Journal of the Air & Waste Management
        Association, Industrial and Engineering Chemistry Research, Water Air and Soil
        Pollution, and Science of the Total Environment.

PUBLICATIONS
Peer-Reviewed
(* - author is a current or former student of mine; § work performed as an undergraduate intern)

1. **Rodenburg, L.A.,** Hermanson, M.R., Sumner, A.L. Effect of membrane filtration on the fate
    of polychlorinated biphenyls in wastewater treatment. *Chemosphere*, **2022,** *287*.
    10.1016/j.chemosphere.2021.132335

2. Lin, Y.; Capozzi, S.L.*, Lin, L.; **Rodenburg, L. A.** Source Apportionment of Perfluoroalkyl Substances in Great Lakes Fish. *Environmental Pollution*, **2021**, *290*, 118047.

3. Almnehlawi, H.; Dean, R. K.; Capozzi, S. L.*; **Rodenburg, L.A.**; Zylstra, G. J.; Fennell, D. E. *Agromyces* and *Arthrobacter* isolates from surficial sediments of the Passaic River degrade dibenzofuran, dibenzo-p-dioxin and 2-monochlorodibenzo-p-dioxin. *Bioremediation Journal*, **2021**, DOI: 10.1080/10889868.2021.1892027

4. Lin, Y.; Jiang, J. J.; **Rodenburg, L. A.**; Cai, M. G.; Wu, Z.; Ke, H. W.; Chitsaz, M.*, Perfluoroalkyl substances in sediments from the Bering Sea to the western Arctic: Source and pathway analysis. *Environment International* **2020**, 139.

5. Lin, Y.; Liu, L.; Cai, M. G.; **Rodenburg, L. A.**; Chitsaz, M.*; Liu, Y. G.; Chen, M.; Deng, H. X.; Ke, H. W., Isolating different natural and anthropogenic PAHs in the sediments from the northern Bering-Chukchi margin: Implications for transport processes in a warming Arctic. *Science of the Total Environment* **2020**, 736.

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Other
1. **Rodenburg, LA** and Leidos. Green-Duwamish River Watershed Addendum to PCB Congener Study: Phase 2 Source Evaluation Report. Prepared for State of Washington Department of Ecology Toxics Cleanup Program. 2018.
2. **Rodenburg,** LA and Leidos. Green-Duwamish River Watershed PCB Congener Study: Phase 2 Initial Data Assessment. Prepared for State of Washington Department of Ecology Toxics Cleanup Program. 2017.
3. **Rodenburg, LA** and Leidos. Green-Duwamish River Watershed PCB Congener Study: Phase 2 Source Evaluation. Prepared for State of Washington Department of Ecology Toxics Cleanup Program. 2017.
4. Du*, S.; **Rodenburg, LA**. "Measurement and Modeling of Semivolatile Organic Compounds in Local Atmospheres." In: *Biophysico-Chemical Processes of Anthropogenic Organic Compounds in Environmental Systems.* Baoshan Xing, Ed. Pp. 149-184, 2010.
5. **Totten, LA.** "The Importance of Atmospheric Interactions to PCB cycling in the Hudson and Delaware River Estuaries." In: *PCBs: Human and Environmental Disposition and Toxicology.* LG Hansen and LW Robertson, Eds. University of Illinois Press, Chicago, IL, pp. 51-59, 2008.
6. **Rodenburg, LA.** "Appendix B: Summary Of Mass Balances On Selected Polycyclic Aromatic Hydrocarbons (PAHs) In The NY/NJ Harbor Estuary." In: *Pollution Prevention And Management Strategies For Polycyclic Aromatic Hydrocarbons In The New York/New Jersey Harbor.* Report by the New York Academy of Sciences, pp. 139-141, 2007. Available at: http://www.nyas.org/programs/harbor.asp
7. **Totten, L. A.** "Present-Day Sources and Sinks for Polychlorinated Biphenyls (PCBs) in the Lower Hudson River Estuary," In: *Pollution Prevention And Management Strategies For Polychlorinated Biphenyls In The New York/New Jersey Harbor.* Report by the New York Academy of Sciences, pp. 84-96, 2005. Available at: http://www.nyas.org/programs/harbor.asp
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9. Baker, J. E.; **Totten, L. A.**; Gigliotti, C. L.; Offenberg, J. H.; Eisenreich, S. J.; Bamford, H. A.; Huie, R. E.; Poster, D. L. Response to Comment on "Reevaluation of Air-Water Exchange Fluxes of PCBs in Green Bay and Southern Lake Michigan." *Environ. Sci. Technol.* **2004,** *38*, 1629-1632.
10. **Totten, L. A.**; Assaf-Anid, N. M. "Abiotic Dehalogenation by Metals." In: *Dehalogenation: Microbial Processes and Environmental Application*. Haggblom, M.M.; Bossert, I. D., Eds. Kluwer: New York, 2002.
11. Eisenreich, S. J.; Gigliotti, C.L.; Brunciak, P. A.; Dachs, J.; Glenn IV, T. R.; Nelson, E. D.; **Totten, L. A.**; VanRy, D.A. "Persistent Organic Pollutants in the Coastal Atmosphere of the Mid-Atlantic States-USA." In: *Persistent Bioaccumulative Toxic Organic Compounds*. R. Lipnick, Ed. American Chemical Society Symposium Series: Washington, D. C., 2000.

PRESENTATIONS

Invited lectures

Rodenburg, LA. In advertent PCBs: An Introduction. Keynote address to the Inadvertent PCB workshop held by the Spokane River Regional Toxics Task Force, October 7-9, 2019.

Rodenburg, LA. Suitability of Spokane River data for fingerprinting. Oral presentation to the Data Suitability Workshop held by the Spokane River Regional Toxics Task Force, May 30-31, 2019.

Rodenburg, LA. PCBs: An Update. Webinar presented September 25, 2017 for the Office of Continuing Professional Education. Available online at: youtube.com

Rodenburg, LA. Why are PCBs and PCDD/Fs dechlorinated by bacteria in some places but not others? Oral presentation. SETAC 38th Annual Meeting in North America, Minneapolis, MN, November 12-16, 2017.

Rodenburg, LA. Green-Duwamish River Watershed PCB Congener Study: Phase 2 Initial Data Assessment. Webinar for the Spokane River Toxics Taskforce. April 26, 2017.

Rodenburg, LA. Green-Duwamish River Watershed PCB Congener Study: Phase 2 Initial Data Assessment. Green-Duwamish Watershed Pollutant Loading Assessment Technical Advisory Committee. Tukwila, WA. March 15, 2017.

Rodenburg, LA. Green-Duwamish River Watershed PCB Congener Study: Phase 2 Initial Data Assessment. US EPA Region 10 and Washington State Department of Ecology. Seattle, WA. March 14, 2017.

Rodenburg, LA. Environmental Data Mining, or How to do Research with No Money.   Special seminar, University of Maryland College Park, Department of Civil and Environmental Engineering. December 7, 2015.

Rodenburg, LA. Environmental Data Mining, or How to do Research with No Money.   Special seminar, The Johns Hopkins University, Department of Geography and Environmental Engineering. December 8, 2015.

Rodenburg, LA. Microbial Dechlorination of PCBs—it's not just for sediments any more. 250th ACS National Meeting, Boston, MA, August 16-20, 2015.

Rodenburg, LA. Identifying non-Aroclor PCB sources through fingerprinting. Spokane River Regional Toxics Taskforce PCB Workshop. January 12-13, 2015, Spokane, WA.

Rodenburg, LA. Fingerprinting And Source Apportionment Of PCBs And BDEs. Eighth International Conference on Remediation and Management of Contaminated Sediments (Battelle), January 12-15, 2015, New Orleans, LA.

Rodenburg, LA., Krumins, V.; Crowe-Curran, J.   Dechlorination of PCBs in the groundwater of the Portland Harbor. Teleconference presentation to Region 10 EPA. January 5, 2015.

Rodenburg, LA. Identifying non-Aroclor PCB sources through fingerprinting. 8th International PCB Workshop, October 5-9, 2014, Woods Hole, MA.

Guo, J.*; Praipipat, P.*; **Rodenburg, LA.** PCBs in pigments, inks, and dyes: Documenting the problem. 17th Annual Green Chemistry & Engineering Conference (American Chemical Society Green Chemistry Institute). June 19, 2013.

Rodenburg, LA. PCBs in consumer products, or how to do research with no money. Oral presentation, Department of Civil and Environmental Engineering, Temple University. March 22, 2013. Philadelphia, PA.

Rodenburg, LA. Stormwater PCBs: Tales from two urban estuaries. Oral presentation at Spokane River Regional Toxics Task Force. June 5-6, 2012. Spokane, WA.

Rodenburg, LA. Microbial dechlorination of persistent organic pollutants in sewers. Oral presentation, Department of Civil and Environmental Engineering, University of Houston. July 9, 2012. Houston, TX.

Rodenburg, LA. Dechlorination of PCBs and dioxins in sewers: Applications to the Passaic River. Special seminar, Montclair State University. March 21, 2012. Montclair, NJ.

Rodenburg, LA; Cacia, DM. Are urban atmospheric PCB concentrations going down? Oral presentation at the 242nd ACS National Meeting, August 28-September 1, 2011, Denver, CO.

Rodenburg, LA; Du, S; Oseagulu, NU; Guo, J; Fennell, DE. Evidence for dechlorination of PCBs and PCDD/Fs in sewers. Oral presentation at the 242nd ACS National Meeting, August 28-September 1, 2011, Denver, CO.

Rodenburg, LA. Water Quality Management in New Jersey's Waterways. Invited seminar, Fermentation Club, Rutgers University, April 3, 2009.

Rodenburg, LA. Diurnal Cycling of Persistent Organic Pollutants in the Atmosphere. Invited seminar, workshop on "Diurnal (Diel) Cycling of Chemical Constituents in Surface Water and Related Media—Scientific and Regulatory Considerations." New Jersey Department of Environmental Protection, December 12, 2008. Trenton, NJ.

Rodenburg, LA. History of contamination in the Hudson River. Invited seminar, Guangzhou Institute of Geochemistry-South China University of Technology Collaborative Workshop. November 13-15, 2008, Guangzhou, PRC.

Rodenburg, LA. PCBs in the Delaware River. Invited seminar, Guangzhou Institute of Geochemistry-South China University of Technology Collaborative Workshop. November 13-15, 2008, Guangzhou, PRC.

Rodenburg, LA. Water Quality Management in New Jersey's Waterways. Invited seminar, School of Environmental Science and Public Health, Wenzhou Medical College. November 18, 2008, Wenzhou, PRC.

Rodenburg, LA. Investigating Atmospheric PCB Source Types, Locations, And Magnitudes In Urban Areas Of New Jersey. Invited presentation, Fifth PCB Workshop: New Knowledge Gained From Old Pollutants. May 18-22, 2008, Iowa City, Iowa.

Rodenburg, LA. The TMDL for PCBs in the Delaware River. Invited seminar, University of Minnesota, Department of Civil and Environmental Engineering, Minneapolis, MN. April 24, 2008.

Rodenburg, LA. The TMDL for PCBs in the Delaware River. Invited seminar, Kettering College of Medical Arts, Kettering, OH. March 27, 2008.

Rodenburg, LA. Atmospheric deposition to the Hudson River. Invited lecture, New York University, November 6, 2007.

Rodenburg, LA; Du, S.; Xiao, B.; Belton, T.; Fennell, D. E. Source Apportionment of Urban PCBs. Platform presentation SETAC 28th Annual Meeting in North America, November 11-15, 2007, Milwaukee, WI.

Totten, LA. PBDEs in the air and water of the NY/NJ Harbor. NJDEP, Trenton, NJ. June 27, 2007.

Totten, LA. Atmospheric Deposition of PCBs to the NY/NJ Harbor and Delaware River. Plenary Presentation, Hudson-Delaware Chapter, SETAC Annual Meeting, Stockton , NJ. April 27-28, 2007.

Totten, LA. PBDEs in the air and water of the NY/NJ Harbor. Hudson River Foundation. May 3, 2006.

Totten, LA. Invited seminar at City College of New York Chemistry Department. September 26, 2005.

Totten, LA. Sampling for semivolatile organic contaminants in environmental compartments. City College of New York, May 5, 2005.

Totten, LA. Invited seminar, NOAA, Ecosystem Processes Division, Howard Laboratories, Highlands, NJ. October 18, 2004.

Totten, LA, AA Rowe, S Yan. Importance of atmospheric interactions to PCB cycling in the Hudson and Delaware River estuaries. Invited oral presentation, American Chemical Society National Meeting, Philadelphia, August 2004.

Totten, LA, AA Rowe, S Yan, SJ Eisenreich. "Importance of atmospheric interactions to PCB cycling in the Hudson and Delaware River Estuaries." 3rd PCB Workshop on Recent Advances in the Environmental Toxicology and Health Effects of PCBs. Champaign, IL, June 13-15, 2004.

Totten, LA. Invited seminar at Swarthmore College, Swarthmore, PA. April 20, 2004.

Totten, LA. "Present-Day Sources and Sinks for Polychlorinated Biphenyls (PCBs) in the Lower Hudson River Estuary." New York Academy of Sciences, New York City, June 2003.

Totten, LA, CL Gigliotti, DA VanRy, ED Nelson, J Dachs, S Yan, JR Reinfelder, and SJ Eisenreich. "PCBs in the Hudson River Estuary: Atmospheric Inputs and Air-water Exchange." New York Academy of Sciences, New York City, November 2002.

Totten, LA, SJ Eisenreich, PA Brunciak. Evidence for Reactions of PCBs with OH Radical In Urban Atmospheres. 3rd SETAC World Congress, Brighton, United Kingdom, 2000.

Totten, LA, AL Roberts. Alkyl Bromides as Mechanistic Probes of Reductive Dehalogenation: Reactions with Zero-Valent Metals. Graduate Student Paper Award Presentation given at the American Chemical Society Annual Meeting, Boston, MA, August 1998.

Presentations at conferences

Capozzi, S.L.; Merjan, C.; Rectanus, H.V.; Chitsaz, M.M; **Rodenburg, L.A**.; Mack, E.E. Using Factor Analysis to Assess Bioremediation Efforts at a Contaminated Site in South America. Poster presentation at SERDP ESTCP 2019 Symposium in Washington D.C., December 3 – 5, 2019.

Rodenburg, LA. Silicones (siloxanes) as environmental sources of polychlorinated biphenyls (PCBs). Oral Presentation. SETAC 40th Annual Meeting in North America, Toronto, Canada, November 3-7, 2019.

Rodenburg, LA. PCB metabolism by benthic organisms vs. otters in the Green-Duwamish River (Seattle). Oral Presentation. SETAC 40th Annual Meeting in North America, Toronto, Canada, November 3-7, 2019.

Rodenburg, LA. Sources of Polychlorinated Biphenyls to Upper Hudson River Sediment Post-Dredging. SETAC 40th Annual Meeting in North America, Toronto, Canada, November 3-7, 2019.

Rodenburg, LA. Choosing the right version of Positive Matrix Factorization. Poster Presentation. SETAC 40th Annual Meeting in North America, Toronto, Canada, November 3-7, 2019.

Capozzi, S.L.; Merjan, C.; Voese, P.; Chitsaz, M.M; **Rodenburg, L.A**.; Mack, E.E. Using Factor Analysis to Assess Bioremediation Efforts at a Contaminated Site in South America. Oral presentation at the Fifth International Symposium on Bioremediation and Sustainable Environmental Technologies in Baltimore, MD, April 15 – 18, 2019.

Merjan, C.; Voese, P.; Capozzi, S. L.; Chitsaz, M.M.; **Rodenburg, L.A.;** Henderson, J.K.; Mack, E.E. Application of Principal Component Analysis to Improve Conceptual Site Models. Poster presentation at the Fifth International Symposium on Bioremediation and Sustainable Environmental Technologies in Baltimore, MD, April 15 – 18, 2019.

Almnehlawai, H.; Dean, R. K.; Capozzi, S. L.; **Rodenburg, L. A**.; Fennell, D. E. Aerobic Degraders of Dibenzofuran and Dibenzo-p-dioxin in the Passaic River and Characterization of their Functional Genes. Poster presentation at the American Society for Microbiology, San Francisco, CA, June 20 – 24, 2019.

Capozzi, S.L.; Ran, J.; **Rodenburg, L.A**.; Kjellerup, B.V. Forensic analysis of polychlorinated biphenyls in wastewater in the Mid-Atlantic region of the USA. Oral presentation at the SETAC North America 39th Annual Meeting in Sacramento, CA, November 4 – 8, 2018.

Capozzi, S.L.; Ran, J.; **Rodenburg, L.A**.; Kjellerup, B.V. Positive Matrix Factorization analysis shows dechlorination of polychlorinated biphenyls during domestic wastewater collection and treatment. Oral presentation at the 10th International PCB Workshop, Krakow, Poland, August 26-31, 2018.

Capozzi, SL; Ran, J; **Rodenburg, LA**; Kjellerup, BV. Oral presentation at the SETAC Young Environmental Scientists Meeting in Madison, WI, March 25 – 29, 2018.

Capozzi, SL; Ran, J; **Rodenburg, LA**; Kjellerup, BV; Wilson, EK. Source apportionment of polychlorinated biphenyls in District of Columbia wastewater. Poster presentation at SERDP ESTCP 2017 Symposium in Washington D.C., November 28-20, 2017.

Capozzi, SL*; Ran, J; **Rodenburg, LA**; Kjellerup, BV; Wilson, EK. Source apportionment of polychlorinated biphenyls in District of Columbia wastewater. Poster. SETAC 38th Annual Meeting in North America, Minneapolis, MN, November 12-16, 2017.

Rodenburg, LA. Opportunities and Challenges of Environmental Data Mining. Oral Presentation. SETAC 38th Annual Meeting in North America, Minneapolis, MN, November 12-16, 2017.

Chitsaz MM*; **Rodenburg, LA**. PCB cycling in stormwater in an urban high desert: Santa Fe, NM. Poster. SETAC 38th Annual Meeting in North America, Minneapolis, MN, November 12-16, 2017.

Capozzi, SL*; **Rodenburg, LA**; Krumins, V; Fennell, DE; Mack, EE. Using Positive Matrix Factorization to Investigate Microbial Dehalogenation of Contaminants in Groundwater. Fourth International Symposium on Bioremediation and Sustainable Environmental Technologies (Battelle). Miami, FL, May 22-25, 2017.

Capozzi, SL*; Ran, J; **Rodenburg, LA**; Kjellerup, BV; Wilson, EK. Source apportionment of polychlorinated biphenyls in District of Columbia wastewater. Poster presentation at the 2017 Chesapeake Potomac Regional Chapter of the Society of Environmental Toxicology and Chemistry, Annapolis, MD, 2017.

Capozzi, SL*; Ran, J; **Rodenburg, LA**; Kjellerup, BV; Wilson, EK. Source apportionment of polychlorinated biphenyls in District of Columbia wastewater. Oral presentation at the 254th American Chemical Society Fall National Meeting & Exposition, Washington, DC, 2017.

Rodenburg LA, and Du, S*. Data Mining and Source Apportionment to Understand Sources and Fate of PCBs. Poster presentation, 9th International PCB Workshop, October 9-13, 2016 Kobe, Japan.

Rodenburg LA, Capozzi, SL*. Data Mining To Answer Complex Environmental Questions. Platform presentation SETAC 37th Annual Meeting in North America, Orlando, FL, November 6-10, 2016.

Rodenburg, LA; Fahrenfeld, N; Blackburne, B[§]. Factors controlling antibiotics levels in biosolids. Poster presentation SETAC 37th Annual Meeting in North America, Orlando, FL, November 6-10, 2016.

Blackburne, B; Fahrenfeld, N; **Rodenburg, LA**; Factors controlling antibiotics levels in biosolids. American Chemical Society, 252nd National Meeting, August 21-25, 2016, Philadelphia, PA.

Williams, L; Klein A; Milne M; **Rodenburg L**; Fuchs V; Lindsay R. Analyzing Toxics At Parts Per Quadrillion Levels In The Collection System And Treatment Plant Effluent. WEFTEC 2015, September 26-30, 2015, Chicago, IL.

Uram, A[§]; Guo, J*; **Rodenburg LA,** Capozzi, SL*. Linking contaminated buildings to atmospheric levels of polychlorinated biphenyls. 8th International PCB Workshop, October 5-9, 2014, Woods Hole, MA.

Capozzi, S*; **Rodenburg, LA**; Guo, J*; Murphy, A[§]; Fennell, DE. Degradation of PCBs by anaerobic bacteria in sewers.   8th International PCB Workshop, October 5-9, 2014, Woods Hole, MA.

Capozzi, S; **Rodenburg, LA**; Guo, J; Murphy, A; Fennell, DE. Degradation of halogenated pollutants by anaerobic bacteria in sewers. Oral presentation, 2013 North America meeting of the Society for Environmental Toxicology and Chemistry (SETAC). November, 2013.

Rodenburg, LA; Guo, J; Capozzi, S; Murphy, A; Fennell, DE. Degradation of flame retardants by anaerobic bacteria in sewers. Poster presentation, 2013 North America meeting of the Society for Environmental Toxicology and Chemistry (SETAC). November, 2013.

Rodenburg, LA; Guo, J; Praipipat, P; Capozzi, S; Murphy, A; Kraeutler, T. PCBs from pigments in children's clothing, crayons, and paper. Poster presentation, 2013 North America meeting of the Society for Environmental Toxicology and Chemistry (SETAC). November, 2013.

Rodenburg, LA; Guo, J; Praipipat, P. PCBs in pigments, inks, and dyes. Oral presentation at the Hudson-Delaware Chapter of SETAC. May 2, 2013, Edison, NJ.

Rodenburg, LA. PCBs in consumer products, or how to do research with no money. Oral presentation, Department of Environmental Science, Rutgers University. April 12, 2013. New Brunswick, NJ.

Rodenburg, LA; Greenfield, BK; Klosterhaus, SL; Yee, D. Photolytic and microbial debromination of BDEs in San Francisco Bay. Oral presentation at the SETAC North America 33nd Annual Meeting, November 2012, Long Beach, CA.

Rodenburg, LA; Guo, J; Du, S; Fikslin, TJ; Cavallo, GJ. Atmospheric deposition of PCBs to the Delaware River. Oral presentation at the SETAC North America 33nd Annual Meeting, November 2012, Long Beach, CA.

Sandy, AL; **Rodenburg, LA**; Miskewitz, RJ; McGillis, WR; Guo, J. Air-water Exchange Fluxes and Mass Transfer Coefficients for PCBs on the Hudson River. Oral presentation at the SETAC North America 32nd Annual Meeting, November 13-17, 2011, Boston, MA.

Rodenburg, LA; Guo, J; Du, S; Oseagulu, NU; Fennell, DE. Are Dioxins Dechlorinated in Sewers? Oral presentation at the SETAC North America 32nd Annual Meeting, November 13-17, 2011, Boston, MA.

Sandy, AL; **Rodenburg, LA**; Guo, J; Miskewitz, RJ; McGillis, WR. Air-water exchange fluxes and mass transfer coefficients for PCBs on the Hudson River. Oral presentation at the 242nd ACS National Meeting, August 28-September 1, 2011, Denver, CO.

Rodenburg, LA; Du, S; Fennell, DE; Cavallo, GJ. Evidence For Extensive Dechlorination Of PCBs In Sewers, Landfills, And Contaminated Groundwater. Oral presentation at Dioxin 2010, 30th International Symposium on Halogenated Persistent Organic Pollutants (POPs), September 12-17, 2010, San Antonio, TX.

Rodenburg, LA; Du, S; Fennell, DE; Cavallo, GJ. Evidence For Extensive Dechlorination Of PCBs In Sewers, Landfills, And Contaminated Groundwater. Oral presentation, 6th International PCB Workshop, May 20-June 2, 2010, Visby, Sweden.

Sandy, AL; Miskewitz, RJ; **Rodenburg, LA.** Direct Measurement of Air/Water Exchange Mass Transfer Coefficients for Polychlorinated Biphenyls using the Micrometeorological Technique. Poster presentation SETAC 30th Annual Meeting in North America, November 19-23, 2009, New Orleans, LA.

Guo, J; Du, S; **Rodenburg, LA**; Cavallo, GJ. Sources of the non-Aroclor congener PCB 11 (3,3'-dichlorobiphenyl) in urban waterways. Poster presentation SETAC 30th Annual Meeting in North America, November 19-23, 2009, New Orleans, LA.

Guo, J; Du, S; **Rodenburg, LA**; Cavallo, GJ. PCB 11 (3,3'-dichlorobiphenyl) in Urban Waterways From Non-Aroclor Sources. Oral presentation American Chemical Society Northeastern Regional Meeting; October 7, 2009; Hartford, CT.

Park, J-W; Krumins, V; Kjellerup, BV; Gillespie, KM; Fennell, DE; Kerkhof, LJ; **Rodenburg, LA**; Sowers, KR; Häggblom, MM. Anaerobic PCB dechlorination by pentachloronitrobenzene-activated Dehalococcoides spp. American Society for Microbiology 2009 General Meeting; May 17 -21, 2009; Philadelphia, PA.

Krumins, V; Park, J-W; Du, S; **Rodenburg, LA**; Häggblom, MM; Kerhkof, LJ; Fennell DE. Reductive Dechlorination of PCBs in Biostimulated Contaminated Sediment. American Society for Microbiology 2009 General Meeting; May 17 -21, 2009; Philadelphia, PA.

Liu, H; Park, J-W; **Rodenburg, LA**; Fennell, DE; Haggblom, MM. Microbial Community Analysis after Dechlorination Stimulating Treatments of Polychlorinated Dibenzo-p-dioxin and Dibenzofuran Contaminated Sediment. American Society for Microbiology 2009 General Meeting; May 17 -21, 2009; Philadelphia, PA.

Rodenburg, LA; Belton, TJ; Du, S; Sandy, AL; Rowe, AA. Atmospheric deposition, source apportionment, and the TMDL for PCBs in the Delaware River, USA. Oral presentation at the 5th SETAC World Congress, 3 - 7 August 2008, Sydney, Australia.

Rodenburg, LA; Krumins, V; Park, J-W; Haggblom, MM; Kerhkof, LJ; Fennell, DE. Stimulation of PCB Dechlorination and Dechlorinators in Contaminanted Sediments. Oral presentation at the 5th SETAC World Congress, 3 - 7 August 2008, Sydney, Australia.

Asher, BJ; Wong, CS; **Rodenburg, LA**. Chiral signatures as a tool for source apportionment of PCBs in the Hudson River Estuary. Platform presentation SETAC 28th Annual Meeting in North America, November 11-15, 2007, Milwaukee, WI.

Rodenburg, LA. PCB sources and fate in New Jersey. Platform presentation SETAC 28th Annual Meeting in North America, November 11-15, 2007, Milwaukee, WI.

Rodenburg, LA; Zarnadze, A. Water column partitioning of BDEs in the New York/New Jersey Harbor. Platform presentation SETAC 28th Annual Meeting in North America, November 11-15, 2007, Milwaukee, WI.

Asher, BJ; Wong, CS; **Totten, LA**. Chiral signatures as a tool for source apportionment of PCBs in the Hudson River Estuary. Oral presentation, American Chemical Society National Meeting, Boston, MA, August 19-23, 2007.

Fennell, DE; Krumins, V; Ravit, B; **Totten, LA**. Bioremediation approaches for PCB- and PCDD/F-contaminated sediments. Oral presentation, American Chemical Society National Meeting, Boston, MA, August 19-23, 2007.

Du, S.; Xiao, B.; Belton, T.; Fennell, D. E.; **Totten, LA.** Source apportionment of PCBs in the Delaware River and NY/NJ Harbor. Oral presentation, American Chemical Society National Meeting, Boston, MA, August 19-23, 2007.

Sandy, A. L.; Du, S.; Kaczorowski, D. M.; **Totten, LA.** Atmospheric PCB sources to the Delaware River. Oral presentation, American Chemical Society National Meeting, Boston, MA, August 19-23, 2007.

Totten, LA; Du, S; Stenchikov, G. Modeling atmospheric POP dynamics in urban systems. Oral presentation, American Chemical Society National Meeting, Boston, MA, August 19-23, 2007.

Xiao, B.; Du, S.; Fennell, D. E.; **Totten, L. A**. Source apportionment of POPs in the NY/NJ Harbor. Oral presentation, American Chemical Society National Meeting, Boston, MA, August 19-23, 2007.

Zarnadze, A.; **Totten, L. A**. Brominated diphenyl ethers in the New York/New Jersey Harbor. Oral presentation, American Chemical Society National Meeting, Boston, MA, August 19-23, 2007.

Kaczorowski, DM; Sandy, AL; Wall, SJ; **Totten, LA**. Investigating the correlation of atmospheric polychlorinated biphenyl concentrations with several variables in Camden, NJ. Poster presented at the Hudson-Delaware Chapter of SETAC Annual Meeting. April 26-27, 2007.

Du, S; **Totten, LA**. Source Apportionment of PCBs in the Delaware River Estuary. Oral presentation at the Hudson-Delaware Chapter of SETAC Annual Meeting. April 26-27, 2007.

Sandy, AL; Du, S; **Totten, LA**. Atmospheric deposition sources of PCBs to the Delaware River. Oral presentation at the Hudson-Delaware Chapter of SETAC Annual Meeting. April 26-27, 2007.

Häggblom, M.M.; Fennell, D.E.; Kerkhof, L.J.; **Totten, L.A**.; Sowers, K.R.; Ahn, Y.-B.; Liu, F.; Liu, H.; Park, J.-W.; Krumins, V. 2006. Quantifying Enhanced Microbial Dehalogenation of Organohalide Mixtures in Contaminated Sediments. Partners in Environmental Technology Technical Symposium & Workshop sponsored by SERDP and ESTCP. November 28-30, 2006. Washington, D.C.

Pagnout C.; Ní Chadhain, S. M.; **Totten, L. A.**; Zylstra, G. J.; Kukor, J. J. Molecular characterization of microbial community shifts occurring in Passaic River sediments during enrichment on biphenyl and monochlorobiphenyls. 5th Tripartite Workshop in Biotechnology and Bioenergy (NJ, USA), April 2007.

Pagnout, C.; Ní Chadhain, S. M.; **Totten, L. A.**; Zylstra, G. J.; Kukor, J.J. Microbial Diversity Shifts in Sediment Enrichment Cultures during the Aerobic Degradation of Biphenyl and

Mono-Chlorinated Biphenyls. American Society for Microbiology, General Meeting, Toronto, Canada, May 21-25, 2007.

Fennell, D.E., Liu, F., Son, E.-K., Zarnadze, A., Krogmann, U., **Totten, L.A.** Fate of Brominated Flame Retardants in New Jersey Wastewater Treatment Facilities. Oral presentation at the USDA NEC 1010 Meeting, Ithaca, NY, October 18-19, 2006.

Zarnadze, A.; **Totten, LA**. BDEs in the New York/New Jersey Harbor, USA. Poster presentation at the SETAC 27th Annual Meeting in North America, 5-9 November 2006, Montreal, Canada.

Du, S; **Totten, LA**. PCB sources to the Delaware River, USA. Oral presentation at the SETAC 27th Annual Meeting in North America, 5-9 November 2006, Montreal, Canada.

Totten, LA; Rowe, AA; Panangadan, M. Atmospheric Deposition and Volatilization of PCBs in the tidal Delaware River. Oral presentation at SETAC 26th Annual Meeting in North America, 13-17 November 2005, Baltimore, Maryland, USA.

Du, S; **Totten, LA**. Attempts to Identify Atmospheric PCB sources in the Philadelphia Metro Area. Oral presentation at SETAC 26th Annual Meeting in North America, 13-17 November 2005, Baltimore, Maryland, USA.

Totten, LA. A Mass Balance On PCBs and PAHs in the NY/NJ Harbor Estuary. Oral presentation at SETAC 26th Annual Meeting in North America, 13-17 November 2005, Baltimore, Maryland, USA.

Fennell, DE; Liu, F; Son, E-K; Zarnadze, A; Krogmann, U; **Totten, LA**. Biotransformation of Halogenated Contaminants in Sludges and Enrichments from Municipal Anaerobic Digesters. Oral presentation at SETAC 26th Annual Meeting in North America, 13-17 November 2005, Baltimore, Maryland, USA.

Asher, B; Wong, C; **Totten, LA**. Source apportionment of chiral PCBs in the Hudson River Estuary. Poster presentation at SETAC 26th Annual Meeting in North America, 13-17 November 2005, Baltimore, Maryland, USA.

Totten, LA; Du, S. Atmospheric PCB Sources in the Philadelphia Metro Area. SETAC Hudson-Delaware Chapter Regional Meeting, April 28, 2005.

Du, S; **Totten, LA** Identifying source areas of PCBs to the Camden/Philadelphia atmosphere. Poster presentation, SETAC 25th Annual Meeting, Portland, OR, November 14-18, 2004.

Rowe, AA; **Totten, LA**; Offenberg, JH; Reinfelder, JR; Eisenreich, SJ. Air-water exchange of polychlorinated biphenyls in the Delaware River Basin. Poster presentation, SETAC 25th Annual Meeting, Portland, OR, November 14-18, 2004.

Rowe, AA; **Totten, LA**; Offenberg, JH; Sommerfield, CK; Du, S; Reinfelder, JR; Eisenreich, SJ. Accumulation of PCBs in sediments of the Delaware River Estuary. Poster presentation, SETAC 25th Annual Meeting, Portland, OR, November 14-18, 2004.

Wall, SJ; **Totten, LA**. A Mobile Platform for Air Toxics Monitoring in New Jersey, USA. Poster presentation, SETAC 25th Annual Meeting, Portland, OR, November 14-18, 2004.

Zarnadze, A; **Totten, LA**; Eisenreich, SJ. Measurements of Polybrominated Diphenyl Ethers (PBDEs) in the air and water of NY/NJ Harbor Estuary. Poster presentation, SETAC 25th Annual Meeting, Portland, OR, November 14-18, 2004.

Totten, LA. Importance of atmospheric interactions to PCB cycling in the Hudson and Delaware River Estuaries. Poster presentation, SETAC 25th Annual Meeting, Portland, OR, November 14-18, 2004.

Totten, LA; Litten, SP. Mass Balance On PCBs and PAHs in the NY/NJ Harbor Estuary. Poster presentation, SETAC 25th Annual Meeting, Portland, OR, November 14-18, 2004.

Zarnadze, A, **LA Totten**. Levels of Polybrominated Diphenyl Ethers (PBDEs) in the Atmosphere of New Jersey, USA. Oral Presentation, Dioxin 2004, Berlin, Germany, September 2004.

Polidori, A, BJ Turpin, HJ Lim, **LA Totten**, C Davidson. Characterization Of The Organic Fraction Of Atmospheric Aerosols. Annual Meeting of the American Association for Aerosol Research, Atlanta, GA, October 2004.

Totten, LA, S Litten. Mass Balances On PCBs and PAHs in the NY/NJ Harbor Estuary. Oral presentation at the 36th Mid-Atlantic Industrial and Hazardous Waste Conference, University of Connecticut, Storrs, CT, October 8-10, 2004.

Zarnadze, A, **LA Totten**, DE Fennell, MP Giacalone, U Krogmann. PBDEs in the NY/NJ Harbor estuary. Poster presentation, American Chemical Society National Meeting, Philadelphia, August 2004.

Rowe, AA, S Du, SJ Eisenreich, JH Offenberg, **LA Totten**, A Zarnadze. Accumulation of PCBs in sediments of the Delaware River Estuary. Oral presentation, American Chemical Society National Meeting, Philadelphia, August 2004.

Rowe, AA.; Eisenreich, SJ.; Offenberg, JH.; **Totten, LA**. "Accumulation of PCBs in sediments of the Delaware River Estuary." Oral Presentation, Society of Toxicology and Chemistry 24th Annual Meeting in North America, Austin, Texas, November **2003**.

Yan, S, **LA Totten**, CL Gigliotti, JH Offenberg, SJ Eisenreich, J Dachs, JR Reinfelder. "Air-water exchange controls phytoplankton PCB concentrations in impacted estuaries." Society of Toxicology and Chemistry 24th Annual Meeting in North America, Austin, Texas, November **2003**.

Zhuang, Y, KM Ellickson, SJ Eisenreich, **LA Totten**, JR Reinfelder. "Atmospheric deposition and impacts of trace metals and mercury in the New Jersey Atmospheric Deposition Network (NJADN)." Poster, Society of Toxicology and Chemistry 24th Annual Meeting in North America, Austin, Texas, November **2003**.

Zarnadze, A, **LA Totten,** JH Offenberg, CL Gigliotti, SJ Eisenreich. "Measurements of Poly-brominated Diphenyl Ethers (PBDE) in the air and water of Hudson River Estuary." Poster, Society of Toxicology and Chemistry 24th Annual Meeting in North America, Austin, Texas, November **2003**.

Ellickson, KM, Y Zhuang, BJ Turpin, SJ Eisenreich, **LA Totten**, JR Reinfelder. "Source identification of mercury and other trace metals in New Jersey fine particulate matter (PM2.5) and rain." Poster, Society of Toxicology and Chemistry 24th Annual Meeting in North America, Austin, Texas, November **2003**.

Cardona-Marek, T, KM Ellickson, **LA Totten**, JR Reinfelder. "Mercury Cycling in the Estuarine Zones of the Delaware River." Poster, Society of Toxicology and Chemistry 24th Annual Meeting in North America, Austin, Texas, November **2003**.

Totten, LA, JR Reinfelder, CL Gigliotti, DA Van Ry, J Dachs, JH Offenberg, Y Koelliker, M Panangadan, S Yan, Y Zhuang, SM Goodrow, KM Ellickson, R Gioia, and SJ Eisenreich. "Atmospheric Deposition of Organic and Inorganic Contaminants to the New Jersey Meadowlands." Oral presentation, Meadowlands Symposium, New Jersey Meadowlands Commission, Lyndhurst, NJ, October 9 and 10, **2003**.

Totten, LA, S Yan, and CL Gigliotti. "PCBs: The Lower Hudson River Estuary and the New Jersey Atmospheric Deposition Network." Oral presentation, American Chemical Society National Meeting, New York City, September 2003.

Assaf-Anid, NM, M Blenner, **LA Totten**, Y-B Ahn, DE Fennell, and M Haggblom. "Agreement of computational chemistry predictions of reductive dechlorination pathways with experimental microcosm studies." Poster, American Chemical Society National Meeting, New York City, September 2003.

Rowe, AA, SJ Eisenreich, CL Gigliotti, JH Offenberg, and **LA Totten**. "Interactions of atmospheric polychlorinated biphenyls with the Delaware River Estuary." Oral presentation, American Chemical Society National Meeting, New York City, 2003.

Gigliotti, CL. **LA Totten**, DA VanRy, PA Brunciak, TR Glenn, J Dachs, SJ Eisenreich. "Atmospheric Deposition and Air-Water Exchange of PAHs in the NY/NJ Harbor Estuary." Oral presentation, Society of Environmental Toxicology and Chemistry, 22nd Annual Meeting, Baltimore, Maryland, **2001**.

Totten, LA, CL Gigliotti, DA VanRy, TR Glenn, SJ Eisenreich. "Atmospheric Deposition and Air-water Exchange of Heptachlor in the NY/NJ Harbor Estuary." Oral presentation, Society of Environmental Toxicology and Chemistry, 22nd Annual Meeting, Baltimore, Maryland, **2001**.

Totten, LA, X Liu,DJ Braun, Assaf-Anid, NM. "Use Of Computational Chemistry To Predict Reduction Potentials Of Polychlorinated Biphenyls." Poster, American Chemical Society Annual Meeting, San Diego, CA, April **2001**.

Assaf-Anid, N. Robert Ambrosini, Xuefeng Liu, Lisa Totten. "A Comparison of Computational Chemistry and Bond Contribution Calculations as Tools for Two-electron Redox Determinations of PCBs."   Poster, Society of Environmental Toxicology and Chemistry, 22nd Annual Meeting, Baltimore, Maryland, **2001**.

Totten, LA, CL Gigliotti, DA VanRy, PA Brunciak, TR Glenn, SJ Eisenreich. Atmospheric Deposition and Air-Water Exchange of PCBs in the NY/NJ Harbor Estuary. Poster, Society of Environmental Toxicology and Chemistry, 22nd Annual Meeting, Baltimore, Maryland, **2001**.

Totten, LA, X Liu, DJ Braun, NM Assaf-Anid. "Use Of Computational Chemistry To Predict Reduction Potentials Of Polychlorinated Biphenyls." Poster, American Chemical Society Annual Meeting, San Diego, CA, April **2001**.

Van Ry, DA, TR Glenn, C Schauffele, R Gioia, CL Gigliotti, **LA Totten**, SJ Eisenreich. "Atmospheric PCBs and PAHs from an Urban to a Forested Area in the Mid-Atlantic States." Oral presentation, Society of Environmental Toxicology and Chemistry, 22nd Annual Meeting, Baltimore, Maryland, **2001**.

Assaf-Anid, NM, **LA Totten**, SJ Braun. "Computational chemistry calculations of thermodynamic descriptors for chlorinated aliphatic compounds and PCBs." Poster, Society of Environmental Toxicology and Chemistry National Meeting, Nashville , TN, **2000.**

Braun, DJ, NM Assaf-Anid, LA Totten, "Computational Chemistry: A Novel Approach for Redox Potential Calculations." Oral Presentation, The 32nd Annual Mid-Atlantic Industrial and Hazardous Waste Conference, Rensselaer Polytechnic Institute, 2000.

Cummings, DA, **LA Totten**, T Lectka, AL Roberts. "Computational Methods For Predicting Heats Of Formation Of Halogenated Methyl And Ethyl Radicals." Oral presentation, American Chemical Society Annual Meeting, Anaheim, CA, April **2000**.

Totten, LA, AL Roberts. "Kinetics of inner-sphere reduction reactions of polyhalogenated methanes." Poster, American Chemical Society Annual Meeting, San Francisco, CA, **1997**.

Totten, LA, AL Roberts. "Stereospecificity of vicinal dehalogenation reactions promoted by abiotic reductants." Poster, Environmental Sciences: Water Gordon Research Conference, New Hampton, NH, June **1996**.

Roberts, AL, DR Burris, TJ Campbell, JA Specht, WA Arnold, **LA Totten**.   "Influence of electron transfer pathway on products resulting from metal-promoted reduction of chlorinated ethenes." Oral presentation, IBC International Symposium on Biological Dehalogenation, Annapolis, MD, October 18-19, **1995**.

Totten, LA, AL Roberts. "Investigating electron transfer pathways during reductive dehalogenation reactions promoted by zero-valent metals." Oral presentation, American Chemical Society Annual Meeting, Anaheim, CA, April **1995**.

PAST AND CURRENT SUPPORT
Grants

FY 2021 GAANN Program Competition. Department of Education. 2021-2024. LA Rodenburg, K Dawson, D. Gimenez, U. Krogmann. $405,840.

NY/NJ Harbor Contamination Assessment and Reduction Project: CARP II. NJDOT. 7/1/2016-6/30-2018. LA Rodenburg and RJ Miskewitz. Subcontract to Rutgers: $190,000. Full grant: $4,000,000 to Monmouth U.

Rutgers University Raritan River Initiative. EPA. 7/1/2012-6/30/2015. CC Obropta, B Ravit, LA Rodenburg. $100,000

Using Sewage to Treat Contaminated Sediment. Rutgers Office of Technology Commercialization. 9/1/2012-8/30/2014. LA Rodenburg, RJ Miskewitz. $50,000.

Where is microbial dehalogenation occurring in the groundwater at Chambers Works? DuPont Corporation. 1/1/2012-12/31/2014. LA Rodenburg, V Krumins. $300,000.

Baseline Assessment of Water and Sediment Quality in the Lower Raritan River. Edison Wetlands Association. 1/1/2011 – 12/31/2012. LA Rodenburg, LJ Kerkhof. $50,000.

Talking Creativity: Conversations between Scientists and Artists. RU FAIR mini-grant proposal. 1/1/2011-6/30/2011. F Olin, LA Rodenburg. $4400.

Continuation of the New Jersey Atmospheric Deposition Network (NJADN). Delaware River Basin Commission. 1/1/2010-6/30/2012. Approx. $100,000 per year. LA Rodenburg.

Quantifying Enhanced Microbial Dehalogenation Impacting the Fate and Transport of Organohalide Mixtures in Contaminated Sediments. SERDP. 3/1/2006-2/28/2010. $1,880,000. MM Haggbloom, DE Fennell, LA Totten, LJ Kerkhof, and K Sowers (UMd).

Measuring Indoor Air Quality in "Green" Hotel Rooms. Hartz Mountain Industries. 1/2009-6/2009. $10,000. LA Rodenburg and J Senick (RU Center for Green Building).

A Gas Chromatograph-Mass Spectrometer (GCMS) for the Analysis of Organic Compounds in Marine and Environmental Samples. Cook/NJAES Intramural Awards Program, Research Infrastructure Awards. 3/10/09-6/30/09. $25,500 EL Sikes, P Falkowski, DE Fennell, W Huang, LA Rodenburg and N Yee.

Measuring Indoor Air Quality in "Green" vs. Conventional Residential Construction. BASF Corporation. 9/2008-3/2009. $3,000. LA Rodenburg and J Senick (RU Center for Green Building).

Graduate student fellowship to Andy L. Sandy. Hudson River Foundation. 9/1/08-8/31/09. $16,000. AL Sandy and LA Rodenburg.

Assessing the Status of Women in Engineering at Rutgers University. Office of the Associate VP for Promotion of Women in Science, Engineering and Mathematics, Rutgers University. 7/1/2008-3/31/2009. $7,950. M Baykal-Gursoy, J Bennett, HM Buettner, L Klein, U Krogmann, M Pelegri, LA Rodenburg, PA Roos.

Volatilization of PCBs from the Tappan Zee region of the Hudson River. NJWRRI. 3/1/2008-2/28/2009. $30,000. LA Rodenburg and RJ Miskewitz.

Continued Air Monitoring for PCBs in the Delaware River Estuary via the NJADN. Delaware River Basin Commission. 6/1/08-12/31/09. $70,000. LA Rodenburg

Passive Air Sampling for PCBs in the Philadelphia Area. Delaware River Basin Commission. 10/1/06-12/31/07. $24,000. LA Totten

Continued Air Monitoring for PCBs in the Delaware River Estuary via the NJADN. Delaware River Basin Commission. 10/1/06-12/31/07. $88,000. LA Totten

Insights into the Cycling of PCBs in the NY/NJ Harbor Estuary from Chiral Analysis. NJDEP. 7/1/2006-6/30/2007. $50,000. LA Totten.

Construction of a Flux Chamber to Determine Air–Water Exchange Mass Transfer Coefficients of Hydrophobic Organic Contaminants. Cook/NJAES Intramural Awards Program, Pre-Tenure Faculty Career Development Awards. 3/10/06-6/30/06. $29,540. LA Totten.

An Accelerated Solvent Extraction (ASE) System for Analysis of Anthropogenic and Natural Chemicals in Environmental Samples and Biota. Cook/NJAES Intramural Awards Program, Research Infrastructure Awards. 3/10/06-6/30/06. $34,620. LA Totten, DE Fennell, MM Haggblom, W Huang, L Kerkhof, C Obropta, EL Sikes, LA White.

Source apportionment of organic contaminants in the NY/NJ Harbor Estuary. Hudson River Foundation. 7/1/2005-12/31/2007. $95,300. LA Totten and DE Fennell.

Source Apportionment of PCBs in the Delaware River Estuary. NJDEP. 7/1/2005-6/30/2006. $65,000. LA Totten.

Impacts of Organic Matter Heterogeneity on Desorption and Availability of Sediment-Bound PCBs. NJWRRI. 3/1/2005-2/28/2006. $30,000. W Huang and LA Totten.

Triple Quadrupole GC/MS For Analysis of Trace Organics in Environmental Matrixes. (Instrumentation Grant). Academic Excellence Fund, Rutgers University. 2004-2005. $175,000. LA Totten, DE Fennell, JR Reinfelder, W Huang, BJ Turpin, RM Sherrell, EL Sikes, LA White.

Graduate Student Fellowship to Archil Zarnadze. Hudson River Foundation. 9/1/04-8/31/05. $16,000. A Zarnadze and LA Totten.

Fate of Brominated Flame Retardants in New Jersey Wastewater Treatment Facilities. NJWRRI. 3/1/2004-2/28/2005. $30,000. DE Fennell, LA Totten and U Krogmann.

Continued Measurement and Modeling of Atmospheric PCBs in the Delaware River Basin. Delaware River Basin Commission, $95,000, 2003-2005

Community Based Air Toxics Monitoring Studies. NJDEP, $272,000, 1/1/2003-12/31/2004. LA Totten.

Emissions And Atmospheric Transport Of PCBs And Hg From Stabilized Harbor Sediments. NJ Marine Sciences Consortium, $219,000, 4/3/2003-6/60/2004. JR Reinfelder, LA Totten, G Stenchikov, GP Korfiatis, RI Hires.

Measurement of Atmospheric PCBs in the Delaware River Basin. Delaware River Basin Commission, $316,000, 2001-2005. LA Totten, JR Reinfelder, SJ Eisenreich.

Measurement of PBDEs in the Air and Water of the Hudson River Estuary. Hudson River Foundation, $176,000, 7/1/2002-6/30/2004. LA Totten, SJ Eisenreich.

Characterizing Organic Fine Particulate Matter (PM2.5) for the Pittsburgh Supersite. Electric Power Research Institute, $50,000, 2002. BJ Turpin, LA Totten.

Atmospheric Dry Particle Deposition of POPs and Trace Metals in an Urban- and Industrially-Impacted Mid-Atlantic Estuary. US EPA, $230,000, 2000-2004. LA Totten, SJ Eisenreich, T Holsen.

Consulting projects

Expert witness representing various cities and states suing Monsanto regarding PCB contamination (2017-present)

Spokane River Regional Toxics Task Force (SRRTTF) (2019-present): PCB source identification in the Spokane River.

Chevron (2018-2020): Source apportionment of PCBs and PAHs at the Newtown Creek Superfund Site.

County of Spokane, WA under subcontract to Brown and Caldwell (2014-2018): Source apportionment of PCBs and BDEs in the wastewater of Spokane.

DuPont under subcontract to Geosyntec (2018-2020): Factor analysis to understand degradation of PCE and TCE at a contaminated site.

Washington State Department of Ecology and EPA under subcontract to Leidos (2016-2017): Evaluate and Conduct Factor Analysis On PCB Data From The Green/Duwamish River

New York Academy of Science (2010): Evaluation of on-going sources of organic contaminants to the lower Passaic River.

New York Academy of Science (2005): Mass balance on PAHs in the New York/New Jersey Harbor

New York Academy of Science (2004): Mass balance on PCBs in the New York/New Jersey Harbor